Arnold Schwarzenegger
Governor

ASSESSING POWER QUALITY IMPACTS AND SOLUTIONS FOR THE CALIFORNIA FOOD-PROCESSING INDUSTRY

PIER FINAL PROJECT REPORT

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Prepared By:
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Prepared By:
E2I / EPRI
E. Petrill
Palo Alto, California

Prepared For:
Public Interest Energy Research (PIER) Program
California Energy Commission

Pramod Kulkarni
Contract Manager

Nancy Jenkins
Manager
ENERGY EFFICIENCY RESEARCH OFFICE

Martha Krebs, Ph.D.
Deputy Director
ENERGY RESEARCH & DEVELOPMENT DIVISION

B.B Blevins
Executive Director

Assessing Power Quality Impacts and Solutions for the California Food Processing Industry

1009176

Final Report, June 2004

Cosponsors
Public Interest Energy Research Program (PIER)
California Energy Commission
1516 Ninth Street
Sacramento, California 95814

PIER Project Manager
P. Kulkarni

E2I
3412 Hillview Avenue
Palo Alto, California 94304

E2I Project Manager
E. Petrill

E2I Corporate Headquarters—an affiliate of EPRI• 3412 Hillview Avenue, Palo Alto, California 94304
PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.e2i.org

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EPRI PEAC Corporation

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CITATIONS

This report was prepared by

EPRI PEAC Corporation
942 Corridor Park Blvd
Knoxville, TN 37932

Principal Investigator
M. Stephens

This report was prepared for

Public Interest Energy Research Program (PIER)
California Energy Commission
1516 Ninth Street
Sacramento, CA 95814

and

E2I
3412 Hillview Avenue
Palo Alto, California 94304

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PRODUCT DESCRIPTION

Modern food processing equipment can easily be impacted by very brief voltage reductions, commonly known as voltage sags, originating from utility distribution and transmission systems. Even minor voltage sags can lead to unscheduled process downtime, delayed client orders, loss of clients, and lost revenue. This project, sponsored by the California Energy Commission (CEC), analyzed the impact of power quality on the California food processing industry and made recommendations for short and long-term solutions to power quality problems. The Del Monte Foods Company plant in Modesto, California served as the benchmark industrial plant for this work.

Results & Findings

Voltage sag related downtime is undesirable in any industry, but it is a special problem in seasonal industries such as food processing. In the case of Del Monte's operations at their California plants, most processing occurs from July 1st through October 1st. During this short window, the plants in Modesto, Kingsburg, and Hanford operate 24 hours a day, seven days a week. Due to this short production season, process interruptions for any reason can be costly. Data monitoring and analysis of key systems at the Modesto plant showed that small, low-cost power conditioners can be used to harden food production processes against interruptions. The cost for implementing such solutions on all process areas is estimated at $74,162. Implementation on the systems that are deemed critical is estimated to cost $28,214. Testing of proposed solutions during the off season may lead to even lower cost solutions through the use of lower rated power quality mitigation devices. Besides recommending actions for the Del Monte plant, the report proposes a plan for improving power quality immunity in the California food processing industry as a whole.

Challenges & Objectives

It is the intent of this initial work to help the California food processing industry integrate the use of electricity in their comprehensive supply chain management procedures. This effort begins the development of a power quality immunity specification for process automation tools and components used in the food processing industry. This project meets the California Energy Commission Public Interest Energy Research (PIER) program goal of improving electricity reliability, quality, and sufficiency. This project also meets the secondary goal of improving energy cost and value in California.

Applications, Values & Use

In this initial project, CEC and E2I began the work of understanding the food processing industry and the impact of power quality on these processes. Likewise, Del Monte has become more informed about the effect of power quality on process systems and solutions to make these systems more robust. In order to further improve the response of Del Monte's process systems to power quality disturbances, additional auditing and testing at Del Monte's Kingsburg and Hanford plants and follow-up work at Modesto is recommended.

E2I Perspective

Besides addressing the particular problems of the Del Monte plant, the report presents a roadmap to improved power quality immunity in the California food processing industry. The end goal of the roadmap is to raise awareness and understanding of power quality problems and solutions and to develop a power quality standard for California food processors. The roadmap presented in the report proposes a collaborative effort from the stakeholders with funding from sources such as the CEC, utilities that supply power for food processing, and food processing manufacturers.

Approach

The project team installed power quality monitoring systems at the Del Monte Foods Company plant in Modesto, California to collect real-time performance data from the plant equipment during food production. Using these monitoring data, plant process equipment schematics, and historical plant process performance data, the team defined the overall sensitivity of the system to various power quality disturbances. The team recommended procedures to make the equipment less sensitive to electrical disturbances and suggested further steps both the Del Monte Plant and the entire food processing industry could take to improve power quality immunity.

Keywords

Power quality
Food processing
Voltage sags
Power conditioning

ABSTRACT

The California Energy Commission sponsored this project through the Electricity Innovation Institute to analyze power quality impacts on the California food processing industry and to address short and long-term solutions to power quality problems. The Del Monte Foods Company plant in Modesto, California was chosen as a benchmark industrial plant for this work. Power quality monitoring systems were installed at the plant to collect real time performance data from the plant equipment while the food production was in process. Using this and other data, overall process sensitivities to different power quality disturbances were defined. Equipment sensitivity data were compared with data from other industrial process equipment to determine the level of sensitivity to electrical disturbances. Procedures were recommended to make the equipment less sensitive. This report also contains recommended actions for the both the Del Monte Plant and the entire food processing industry.

It is the intent of this initial work to help the California food processing industry view the use of electricity as a part of their comprehensive supply chain management procedures. This effort marks the beginning of a process that is hoped to foster the development of a power quality immunity specification for process automation tools and components used in the food processing industry. This project meets the California Energy Commission Public Interest Energy Research (PIER) program goal of improving electricity reliability, quality, and sufficiency. This project also meets the secondary goal of improving energy cost and value in California.

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1.1 Overview

The goal of this California Energy Commission (CEC) sponsored project is to analyze the power quality impacts on the California food processing industry and to address short and long-term solutions to power quality problems. The Del Monte Foods Company plant in Modesto, California was chosen as a benchmark industrial plant for this work. Power quality monitoring systems were installed at the plant to collect real time performance data from the plant equipment while the food production was in process. Using this monitoring data, plant process equipment schematics and historical plant process performance data, overall process sensitivities to different power quality disturbances were defined. Equipment sensitivity data were compared with other industrial process equipment to determine the level of sensitivity to electrical disturbances. Procedures were recommended to make the equipment less sensitive. This report also contains recommended actions for the both the Del Monte Plant and the entire food processing industry.

It is the intent of this initial work to help the California food processing industry view the use of electricity as a part of their comprehensive supply chain management procedures. This effort marks the beginning of a process that is hoped to foster the development of a power quality immunity specification for process automation tools and components used in the food processing industry. This project meets the PIER Goal of Improving the Reliability/Quality of California's Electricity. This project also meets the secondary goal of improving the Energy Cost/Value of California's Electricity

1.2 Summary of Efforts at Del Monte's Modesto Plant

EPRI PEAC and CEC visited the Del Monte Modesto facility four times during the course of this project as outlined below:

Site Visit 1: (April 23rd, 2003) Initiative Introduction. Presentation Entitled 'Food Industry PQ Initiative An Application Oriented R&D Program"was given by Dr. Arshad Mansoor. This presentation introduced the program to Del Monte and gave an overview of common power quality problems and solutions. Furthermore, the need for an industry effort and possible power quality standard for the food processing industry was addressed.

Site Visit 2: (May 22nd-23rd, 2002) Initial Site Audit. Brian Fortenbery conducted an initial audit of the Modesto facility. In this audit EPRI PEAC gained an understanding of the Del Monte process at Modesto, including the most critical process areas. A survey of electrical control equipment used was also conducted in order to compare against the EPRI database of known power quality responses.

Site Visit 3: (August 15th, 2002) Technical Training for Del Monte. Mark Stephens and Brian Fortenbery conducted a Power Quality Training and Tech Transfer for Del Monte. EPRI PEAC's initial analysis of the facility was presented as well as typical power quality problems and solutions for making process systems more robust. This visit also included a walkthrough of the process facilities.

Site Visit 4: (September 12th, 2002) Project Review Meeting. Mark Stephens and Brian Fortenbery conducted this meeting that included attendees twenty stakeholders. The purpose of the meeting was to review the vision for the initiative, the basic findings of the power quality audit at Del Monte's Modesto plant, examine known solutions, and review other industry standards efforts that are in place. The attendees to this meeting are listed in Table 1-1.

Table 1-1
Food Industry PQ Initiative Meeting Attendees, September 12th, 2002

Name	Stakeholder Company	Phone	Email
Ed Yates	CA League of Food Processors	916-444-9260	*ed@clfp.com*
Michael Gravely	CEC	916-651-9550	*mgravely@energy.state.ca.us*
Tony Wong	CEC	916-654-4015	*twong@energy.state.ca.us*
Ricardo Amon	CEC	916-654-4019	*ramon@energy.state.ca.us*
Glen Lewis	Del Monte	209-342-1509	*glen.lewis@delmonte.com*
Ron Howes	Del Monte	209-527-3850	*Ron.howes@delmonte.com*
Ben Goff	Del Monte	209-652-6789	*Ben.goff@delmonte.com*
Chris Cockrill	DOE	816-873-3299	*Chris.cockrill@ee.doe.gov*
Mark Stephens	EPRI PEAC	865-218-8022	*Mstephens@epri-peac.com*
Brian Fortenbery	EPRI PEAC	865-218-8012	*bfortenbery@epri-peac.com*
Ken Eklund	Idaho Energy Division	208-327-7974	*keklund@idwr.state.id.us*
Jim Clark	JM Smucker Co	831-786-2023	not given
Patricia Campbell	JM Smucker Co	831-786-2002	*Pat.campbell@jmsmucker.com*
Chris Mayer	Modesto ID	209-526-7430	*chrism@mid.org*
Mike Zweifel	Modesto ID	209-526-7455	*mikez@mid.org*
Brian Wong	PG&E	415-973-3052	*BXW5@PGE.com*
Robert Yamamato	PG&E	559-263-5532	*Rh1@pge.com*
Dan Pope	PG&E	209-726-6393	*Dwp4@PGE.com*
Mike Checketts	PG&E	559-263-5548	*mdca@pge.com*
Pat deWitt	SWEPCO Lubricants	916-996-1072	*racylady@earthlink.u*
Jatal Mannapperuma	UC Davis	530-752-8449	*jdmannapperuma@ucdavis.com*

1.3 Summary of Findings and Recommendations from Modesto Power Quality Analysis

Based on the audit results from the Modesto facility, the most critical areas to protect from power quality related shutdowns are shown in red in Figure 1-1. These include the Cook/Cool, Boiler, and Labeling/Casing processes.

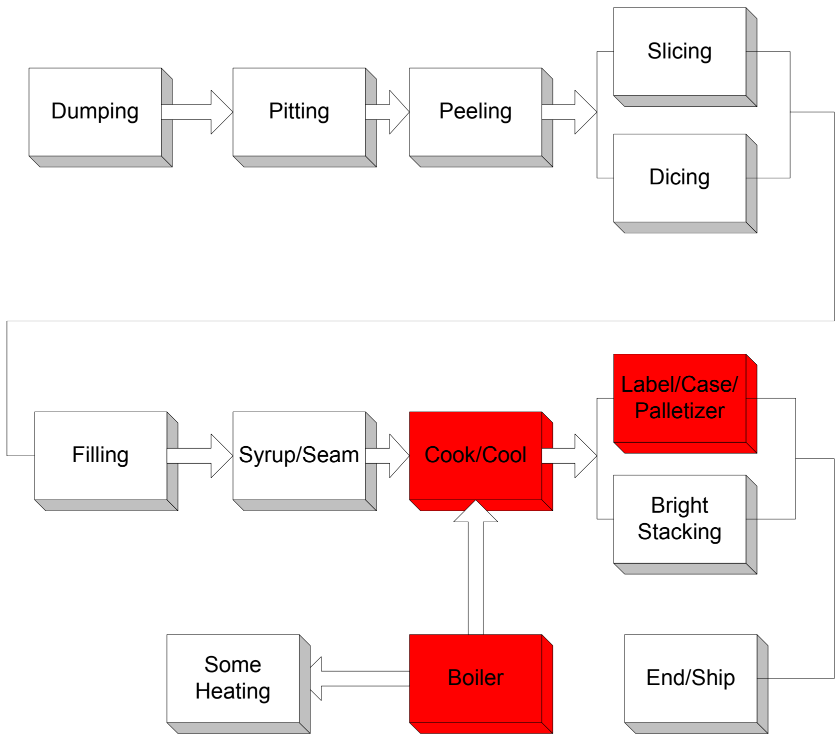


Figure 1-1
Del Monte Fruit Processing Flow Diagram

EPRI PEAC performed an analysis of the entire process and specifically the areas shown in red in Figure 1-1. Based on the analysis, small, low-cost power conditioners can be used harden the Modesto processes. The cost for implementing such solutions on all process areas is estimated at $74,162. Implementation on the systems that are deemed critical is estimated to cost $28,214. Testing of proposed solutions during the off season may lead to even lower cost solutions since power quality mitigation device sizing may be reduced.

1.4 Proposed Future Work With Del Monte

The following work is proposed as a follow-up to this initial project.

1. Power Quality Audit and Testing at Kingsburg Plant. Del Monte has voiced concerns over boiler and process system shutdowns for the Kingsburg plant. Given the product quality problems associated with the shutdown of a tomato processing plant, the problems at this plant should be tackled first. Since the effort at Kingsburg would be a field audit instead of the research and technology transfer type effort that was conducted initially at Modesto, the auditing, testing, and reporting would be accomplished completely within 3 to 4 weeks.

2. Testing and Implementation of the Proposed Solutions at Modesto. Given the recommendations from this report, it would be feasible to test the recommended solutions on the most critical systems. Considering the fact that only limited production takes place in the off season time, it is important to move ahead with this effort so that completed solutions can be installed before the beginning of next year's production season.

3. Power Quality Effort at the Hanford Plant. In order to cover all three of the major fruit and tomato processing facilities for Del Monte, the Hanford plant should be considered for a power quality effort. Proposed tasks for this facility include the installation of I-Grid power quality monitor(s) and power quality auditing and testing at the facility. The estimated start-to-finish time for this work is 4 to 5 weeks.

1.5 Roadmap For Future Efforts

In order to foster improved power quality immunity in the California food processing, an industry roadmap is presented herein. The end goal of the roadmap is two fold:

1. The first goal is to raise awareness and understanding of power quality problems and solutions for the industry

2. The second goal is to develop a power quality standard for in which California food processors will implement in new and existing process systems.

For an overall power quality effort in food processing to be successful, all stakeholders must be involved to work toward feasible solutions. As shown in Figure 1-2, true System Compatibility can only be achieved when the process equipment suppliers, electric utilities, and food processing manufacturers work together. Without the participation of just one of the "legs" of this three-legged stool, it cannot not stand.

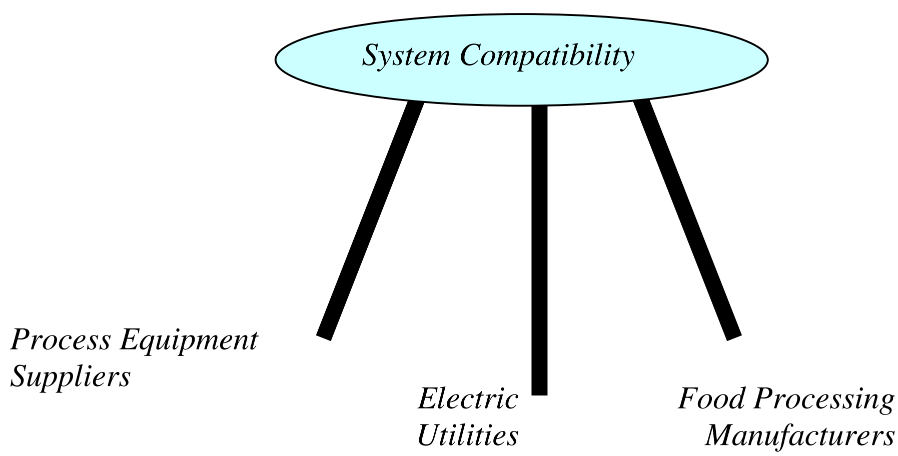


Figure 1-2
System Compatibility for the Food Processing Industry

The roadmap presented herein is based on a collaborative effort from the stakeholders as well as funding from sources such as the California Energy Commission, other utilities who have food processing as a major industry, and potentially food processing manufacturers as well. By combining resources, the end goal of creating a workable and accepted industry standard can be realized. The envisioned tasks are outlined below.

Task 1: Implement Web Based Platform to Manage and Promote this Standards Effort. It is important that such a web site be maintained throughout the entire initiative.

Task 2: Assessment of Impact of PQ Disturbances on Process Automation Equipment for Food Processing Industries. These assessments will be undertaken in cooperation with candidate food processing industries in California and well as other regions in which a stakeholder steps forth to sponsor other work.

Task 3: Develop Target Ranges for Process Equipment Immunity Based on Controlled Testing. Where existing data for components sensitivity is not available, controlled lab testing will be conducted to identify the component level sensitivity.

Task 4: Provide Technical Support to the Food Processing Industry PQ Standards Coordinating Committee. The group must be formed either under the umbrella of a recognized food processing organization or with recognition of major industry organizations.

Task 5: Develop PQ Recommended Practice Document for Electrical Design and Equipment Selection for the Food Processing Industry. This document will provide guidance to plant personnel on properly integrating process equipment to minimize power quality issues for existing plants and for new plants.

Task 6: Technology Transfer Activities. This task will begin from the start of this effort with information posted on the initiative web site. Activities to engage the industry such as participating in industry conferences, tradeshows, and writing technical papers will be included in this work.

The Proposed Schedule for the Roadmap is shown in Figure 1-3.

	Task Name	Duration	Start	Finish
1	Project Start	0 days	Wed 1/1/03	Wed 1/1/03
2	Task 1: Implement and Maintain Standards Web Site	522 days	Wed 1/1/03	Thu 12/30/04
3	Task 2: Assessment of PQ Impact on Process Equipment	9 mons	Mon 2/3/03	Fri 10/10/03
4	Task 3: Develop Target Ranges	3 mons	Mon 6/2/03	Fri 8/22/03
5	Task 4: Support for PQ Standards Effort	414 days	Mon 6/2/03	Thu 12/30/04
6	Task 5: Develop Recommended Practices Document	88 days	Mon 9/1/03	Wed 12/31/03
7	Task 6: Technology Transfer	523 days	Wed 1/1/03	Fri 12/31/04
8	Project Completion	0 days	Fri 12/31/04	Fri 12/31/04

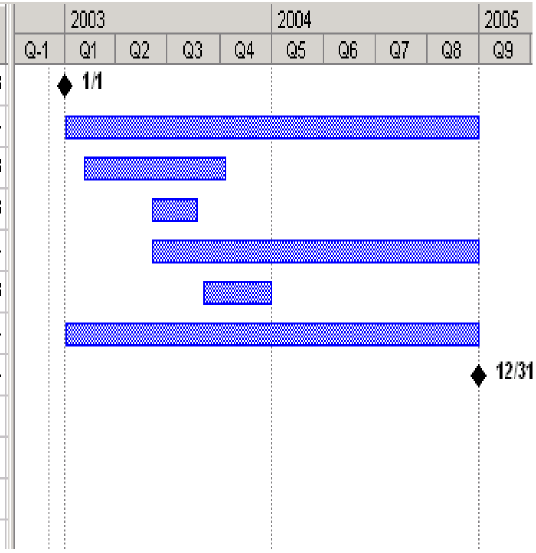


Figure 1-3
Proposed Roadmap Schedule for Food Industry Power Quality Standards Effort

2
INTRODUCTION

2.1 Background

Modern food processing equipment can easily be impacted by very brief voltage reductions – commonly known as voltage sags –originating from utility distribution and transmission systems. Because of the sensitivity of this equipment, minor voltage sags can lead to unscheduled process downtime, delayed client orders, loss of clients, and lost revenue. In most year round processes, voltage sag related downtime is not welcomed, but it may be easier to recover from than seasonal operations.

In the case of Del Monte's operations at their California plants, the majority of the process operations occurs from July 1st through October 1st. During this short window, the plants in Modesto, Kingsburg, and Hanford (Figure 2-1) are operating on 24 hour day, seven days a week schedule. In fact, Del Monte's company-wide food processing production is estimated to be 80 percent seasonal. Due to this short production season, process interruptions for any reason can be costly.

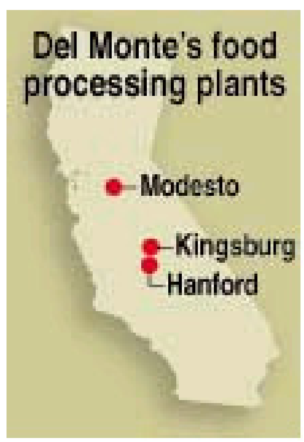


Figure 2-1
Del Monte's California Food Processing Plants

This power quality analysis primarily focuses on the fruit operations at the Modesto facility. In the fruit processing operations, power quality event can lead to one to two hours of downtime. Production line balancing becomes an issue in that the in-feed sections of the plant may become clogged up due to downstream line shutdown. Furthermore, delivery trucks begin to back up in the parking lot waiting to deliver their loads of produce. When an operation is running at a 24/7 pace, supply chain management can become difficult when such conditions arise. This unplanned downtime can lead to lost revenue, product, and possibly delay meeting client orders.

Even though there are problems when process downtime occurs, fruit processing is more forgiving to power quality induced upsets than other operations such as tomato processing conducted at the Hanford plant. Because of the septic packaging nature of tomato processing, a single process upset can lead 24 hour to 36 hours of downtime before the facility can be operational again. This is due to the requirement to dump product and cleanout process lines and pumps to ensure that a sterile processing environment is maintained. Such a response is costly in product loss as well as production downtime. Such loss of product and process downtime is expected to occur in other California food processing facilities. The degree of impact on various other food processes will become more apparent as this initiative work continues.

2.2 Project Goals and Objectives

The goal of this California Energy Commission (CEC) sponsored project is to analyze the PQ impact and short and long-term solutions for the California food processing industry. The Del Monte Foods Company plant in Modesto, California was chosen as a benchmark industrial plant for this work. Power Quality monitoring systems were installed at the plant to collect real time performance data from on the plant equipment while the food production was in-process. Using this monitoring data, plant process equipment schematics and historical plant process performance data, overall process sensitivities to different power quality disturbances were defined. Equipment sensitivity data was compared with other industrial process equipment to determine the level of sensitivity to electrical disturbances and recommended procedures to make the equipment less sensitive. This report also contains recommended actions for the both the Del Monte Plant and the entire Food Processing Industry.

The objectives of the work at the Modesto plant included:

- Power Quality Technical Transfer for Del Monte. This was accomplished by a August 15th, 2002 training class conducted at the Modesto facility.
- Analyze the PQ impact and short and long-term solutions for the CA food processing industry using the Del Monte Foods Company (Del Monte) Plant in Modesto, California as a benchmark. The initial results of the analysis were presented on September 12th, 2002 during a project review meeting at the Modesto facility. This report contains the final analysis.
- Provide Recommendations for making the Modesto Process More Immune to Power Quality Disturbances. The initial recommendations were also conveyed during the September 12th meeting and are further detailed herein.
- Provide General Recommendations for the food processing industry as a whole. General recommendations were presented on September 12th and are also detailed within this report.

3
ELECTRICAL ENVIRONMENT

3.1 Background

In order to understand the power quality environment that will be seen by the food processing industry it is important to understand the types of power quality problems that exist today. The IEEE standard entitled "*1159-1995: Recommended Practice for Monitoring Electric Power Quality*" is an accepted standard for defining the types of power quality phenomenon that can occur (Table 3-1). Furthermore, examples and causes of these disturbances are shown graphically in Table 3-2.

Using these criteria, research and case study investigations over the past decade have identified the following categories of power quality phenomena to be the highest importance to end users:

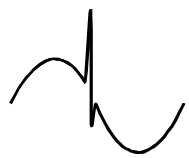
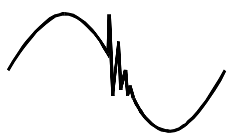
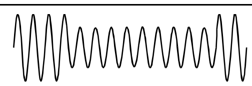
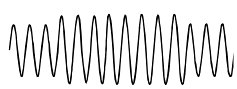
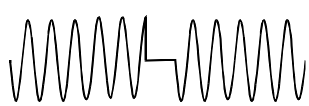
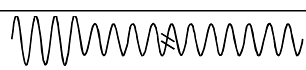
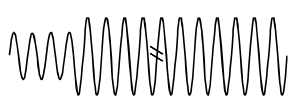
- RMS voltage variations, especially sags and interruptions (Category 2)
- Transients (Category 1)
- Harmonic Distortion (Category 5)

The previous should not be taken to imply that there are never problems associated with other categories of power quality phenomenon. Experience does indicate that the large majority of power quality problems are related to the three items listed.

Table 3-1
IEEE Standard 1159-1995 Categories and Typical Characteristics of Power System Electromagnetic Phenomena

Categories	Typical Spectral Content	Typical Duration	Typical Voltage Magnitude
1.0 Transients			
1.1 Impulsive			
1.1.1 Nanosecond	5 ns rise	<50 ns	
1.1.2 Microsecond	1 μs rise	50 ns–1 ms	
1.1.3 Millisecond	0.1 ms rise	>1 ms	
1.2 Oscillatory			
1.2.1 Low frequency	<5 kHz	0.3–50 ms	0–4 pu
1.2.2 Medium frequency	5–500 kHz	20 μs	0–8 pu
1.2.3 High frequency	0.5–5 MHz	5 μs	0–4 pu
2.0 Short duration variations			
2.1 Instantaneous			
2.1.1 Sag		0.5–30 cycles	0.1–0.9 pu
2.1.2 Swell		0.5–30 cycles	1.1–1.8 pu
2.2 Momentary			
2.2.1 Interruption		0.5 cycles–3 s	<0.1 pu
2.2.2 Sag		30 cycles–3 s	0.1–0.9 pu
2.2.3 Swell		30 cycles–3 s	1.1–1.4 pu
2.3 Temporary			
2.3.1 Interruption		3 s–1 min	<0.1 pu
2.3.2 Sag		3 s–1 min	0.1–0.9 pu
2.3.3 Swell		3 s–1 min	1.1–1.2 pu
3.0 Long duration variations			
3.1 Interruptions, sustained		>1 min	0.0 pu
3.2 Undervoltages		>1 min	0.8–0.9 pu
3.3 Overvoltages		>1 min	1.1–1.2 pu
4.0 Voltage imbalance		steady state	0.5–2%
5.0 Waveform distortion			
5.1 DC offset		steady state	0–0.1%
5.2 Harmonics	0–100th H	steady state	0–20%
5.3 Interharmonics	0–6 kHz	steady state	0–2%
5.4 Notching		steady state	
5.5 Noise	broad-band	steady state	0–1%
6.0 Voltage fluctuations	<25 Hz	Intermittent	0.1–7%
7.0 Power frequency variations		< 10 s	

Table 3-2
Waveform Summary of Power Quality Variation Categories

Example Waveshape or RMS variation	Power Quality Variation Category	Method of Characterizing	Typical Causes
	Impulsive Transients (transient disturbance)	Peak Magnitude,Rise Time,Duration	Lightning, Electro-Static Discharge, Load Switching, Capacitor Switching
	Oscillatory Transients (transient disturbance)	Waveforms, Peak Magnitude Frequency Components	Line/Cable Switching, Capacitor Switching, Load Switching
 sag  swell	Sags/Swells (rms disturbance)	RMS vs. Time, Magnitude, Duration	Remote System Faults
	Interruptions (rms disturbance)	Duration	System Protection (Breakers, Fuses), Maintenance
 undervoltage  overvoltage	Undervoltages/ Overvoltages (steady state variation)	RMS vs. Time, Statistics	Motor Starting, Load Variations, Load Dropping
	Harmonic Distortion (steady state variation)	Harmonic Spectrum, Total Harm. Distortion, Statistics	Nonlinear Loads, System Resonance
	Voltage Flicker (steady state variation)	Variation Magnitude, Frequency of Occurrence, Modulation Frequency	Intermittent Loads, Motor Starting, Arc Furnaces

3.1.1 Voltage Variations

Most end users recognize that electric power outages could never be cost-effectively eliminated. Distribution system reliability in the United States is very high, reflecting the fact that actual electric service interruptions are very infrequent. From the EPRI Distribution Power Quality study, it was found that a customer is almost 10 times more likely to experience a voltage sag than a service interruption. Many modern product equipment and processes will misoperate or shut down in response to even a short duration voltage sag (as defined by Category 2). This reaction, coupled with the relatively high rate of occurrence and the general high cost and complexity of typical solutions, make short term voltage variations one of the most, if not the most, important category of power quality phenomena from the end user point of view. Figure 3-1 is a graphical representation of a short duration sag.

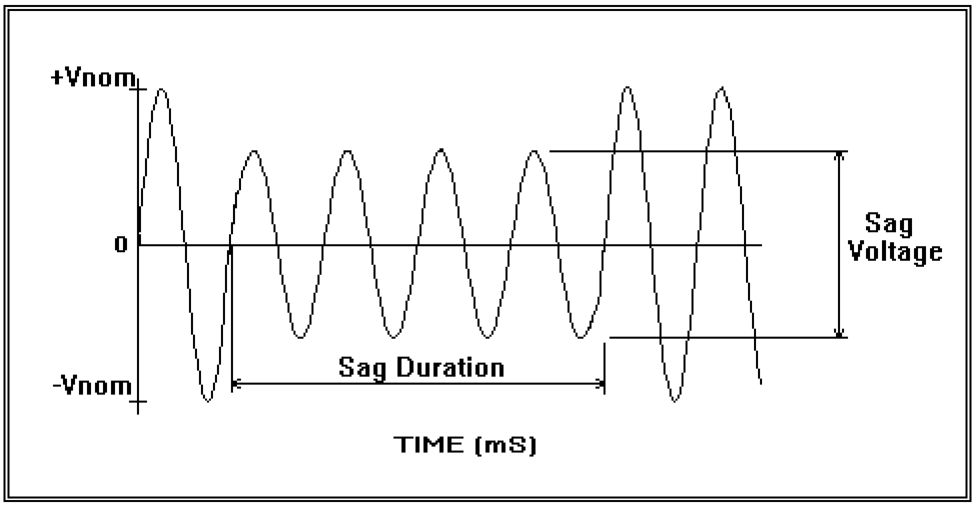


Figure 3-1
Graphical Definition of Sag Voltage

3.1.2 Transients

Transient overvoltages caused by switching operations or lightning strikes to electric facilities have significant potential to damage electric power equipment or disrupt operation. High frequency transients (most impulsive transients and low- and medium frequency oscillatory transients) have been recognized for some time as a threat to electronic equipment, and have been blamed for a wide range of failures and misoperations. Fortunately, these transients are relatively easy to protect against, and a wide range of off the shelf and inexpensive transient voltage surge suppressor products can be applied either by the end user or original equipment manufacturer.

Low frequency oscillatory transients, on the other hand, are more difficult to treat. Switching (energizing) of utility shunt capacitor banks is the most common source of low frequency transients on the electric power system. Unlike the other subcategories of transient phenomena, these are usually of modest magnitudes but contain substantial energy, so their effects can be felt quite far electrically from the point of origin. Low frequency transients have been strongly correlated with "nuisance tripping" of power electronic equipment, especially common types of adjustable speed drives. Figure 3-2 represents transient overvoltage caused by capacitor switching on the utility distribution system and magnification by power factor at customer facility.

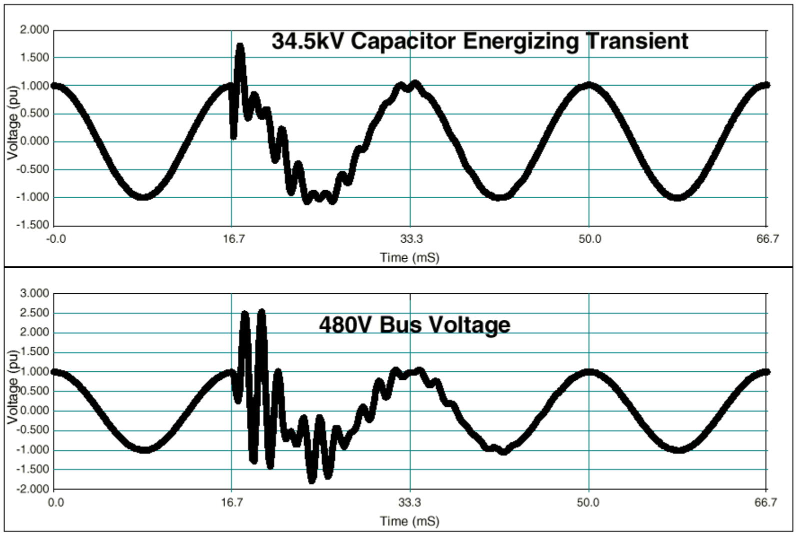


Figure 3-2
Transient overvoltage due to capacitor switching on the utility distribution system (top) and magnification by power factor at customer facility (bottom)

3.1.3 Harmonic Distortion

Harmonics are probably more strongly associated with "power quality" than any other category. It is somewhat surprising to those only casually involved in power quality that harmonics are not a chronic problem that the typical end user must wrestle with. Harmonics can cause equipment to misoperate, capacitor banks to fail, breakers to trip mysteriously, but in general, the electric power system has the ability to absorb substantial amounts of harmonic current with surprisingly little or no impact on connected equipment. Real problems from harmonics are usually confined to locations with inordinate amounts of nonlinear, harmonic current-producing loads (such as wastewater treatment plant where the entire load may be comprised of adjustable speed motor drives powering pumps), or situations where power factor correction capacitors on the end-user system or at the utility distribution level create resonances that amplify the effects of nonlinear loads.

Harmonics have increased significantly over the past two decades due to the increased use of non-linear loads such as adjustable speed motor drives and switch mode power supplies.   As the fraction harmonic load increases, a major concern is that harmonic distortion levels will begin to cause more problems for utilities. Because of this concern, harmonics have received continuous attention from standards-making bodies and technical groups. There have been some "rules of thumb" developed that estimate limits on the percentage of total load represented by adjustable speed drives. Above a certain percentage, IEEE standards for voltage distortion could be exceeded.

3.2 Examination of Power Quality Studies

To further shed light on the most prevalent power quality disturbances that will be seen by the food processing industry, it is important to look at the results from three benchmark power quality surveys. In the 1990's three distinct power quality surveys were conducted to characterize the power quality environment related to voltage variations. Namely, these studies were:

- The Canadian Electric Association (CEA) Study
- The National Power Laboratory (NPL) Study
- The Electric Power Research Institute (EPRI) Distribution Power Quality (DPQ) Study

The CEA Study. This study began in 1991 and ran for three years to determine the general levels of power quality in Canada. The CEA study consisted of power quality data from twenty-two utilities throughout Canada with a total of 550 sites each monitoring for 25 days. Site selection included residential and industrial customers with monitoring voltage ranges from 120Vac to 347Vac. This monitoring was conducted at the service entrance panel.

The NPL Study. In 1990, the NPL initiated a five-year survey of single-phase electrical disturbances. The objective of the survey was to provide a large, well-defined database of recorded disturbances that profiled the power quality at the typical points of usage. Single-phase line-to-neutral data was collected at the standard wall receptacle. Data was collected at 130 sites within the continental United States and Canada.

The EPRI DPQ Study. Beginning in 1990, EPRI commissioned a survey to assess distribution power quality. The goal of the work was to perform the most thorough study to date to describe power quality levels on primary distribution systems in the United States. The collection tool was in place from June 1993 until September 1995. The study involved twenty-four U.S. utilities and 300 different monitoring sites. Through careful data filtering and measurement technique considerations, the power quality data from these three surveys was combined in 1997 to create a composite of the range of events that might be expected at the majority of end user locations. As shown in Figure 3-3, the data has been combined to show the expected number of events per typical site per year.

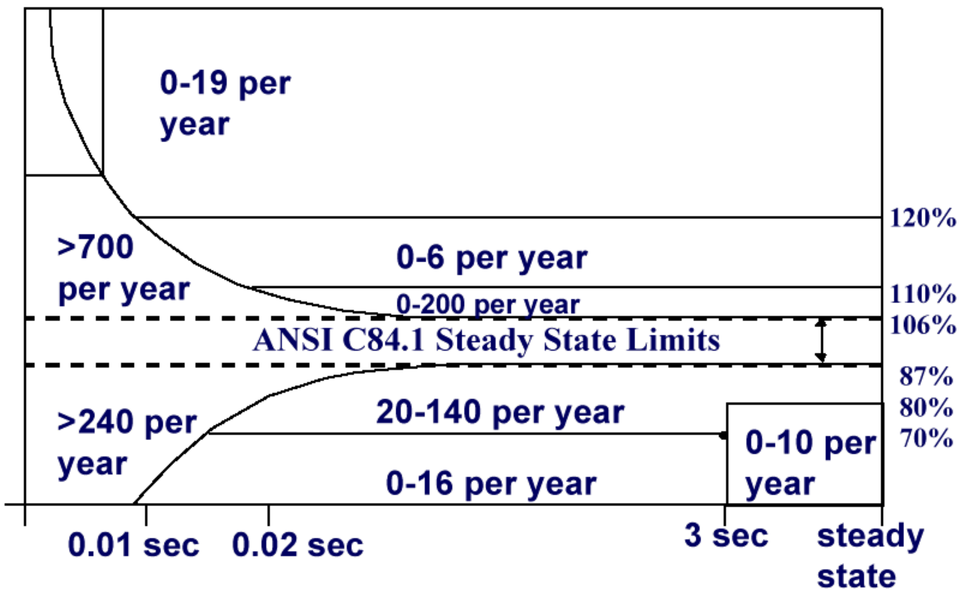


Figure 3-3
Projected 95% Probability for Any Site to Fall Within the Range of Events Shown in a Given Area

Given the combined data from the NPL, CEA, and DPQ study, EPRI experience, and history of industrial customer complaints, protection of end use equipment from voltage sag phenomena is the most important power quality consideration. Although many more short duration disturbances occur (less than 0.01 seconds), there is not a strong correlation with system or equipment shutdowns. From Figure 3-3, a typical site is likely to see 20 to 140 sags down to 70 percent of nominal and an additional zero to 16 events that are below that level. From these power quality events, the most direct correlation can be drawn to equipment shutdowns and lost production.

3.2.1 RMS Voltage Variation Phase Breakout

In order to implement effective power quality mitigation strategies for the food processing industry, is important to better understand the typical nature of the voltage variations that will be seen. This data, recorded as a part of the EPRI DPQ study, was collected by triggering events when the phase voltages either dropped below 0.95pu or rose above 1.05pu. Based on further filtering of the RMS voltage variation results that occurred below 0.9pu and above 1.10pu, voltage sags were found to occur about 15 times more prevalent than overvoltages. Therefore, the data shown in Figure 3-4 overwhelming represents voltage sag events. Furthermore, most events that occurred are single-phase (68 percent), followed by two-phase (19 percent) and three-phase (13 percent).

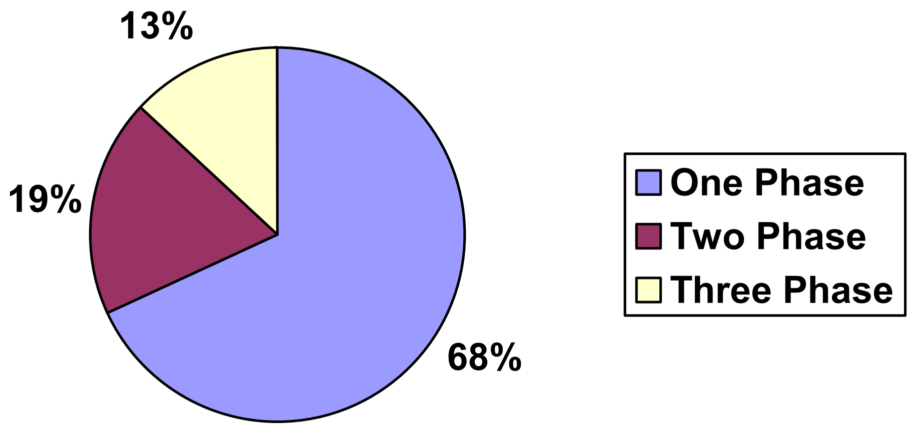


Figure 3-4
Percentage of Phases Effected During RMS Voltage Variations

Based on this information, mitigation strategies that focus on solving single and two-phase events can be quite effective in enabling food processing systems to ride-through voltage sags. It is important to note that events measured on the secondary side of a control power transformer may also represent the actual phase-to-phase percentages as well.

3.3 Voltage Sag Standards

When voltage sags occur in the utility supply, the immunity of the industrial process to the event is important. From the industrial process standpoint, the components within the control panel should be able to survive minor voltage sags without causing the system to trip off line. The use of robust relays, contactors, and power supplies is essential to reach the desired immunity. Research has shown that sensitive relays in the control circuit can lead to industrial process systems shutting down for 1 cycle or more, with magnitudes of 75 percent of nominal or less. Furthermore, the most sensitive programmable logic controller (PLC) systems have been shown to shutdown for voltage sags ranging from 78 to 85% of nominal, lasting only 2 cycles.

Two important standards that should be considered when evaluating the immunity of a food processing system to voltage sags include the lower portion of the ITIC (a.k.a CBEMA 96) curve and the new SEMI F47 standard. The ITIC and SEMI F47 curve are used as benchmarks to evaluate equipment against power quality robustness.

Supplied by the Information Technology Industry Council, the ITIC curve represents the operational tolerance curve that is typical of most information technology equipment. This equipment includes items such as computers, monitors, printers, fax machines and telecommunications equipment. Therefore, the curve define the expected transient, over voltage (voltage swell), and under voltage (voltage sag) conditions in which information technology equipment should operate. There are two-axis to the curve as shown in Figure 3-5. The x-axis represents the duration of the power quality disturbance. The y-axis represents the magnitude of the disturbance. Information technology equipment is expected function normally within voltage tolerance envelope (represented by the shaded regions).

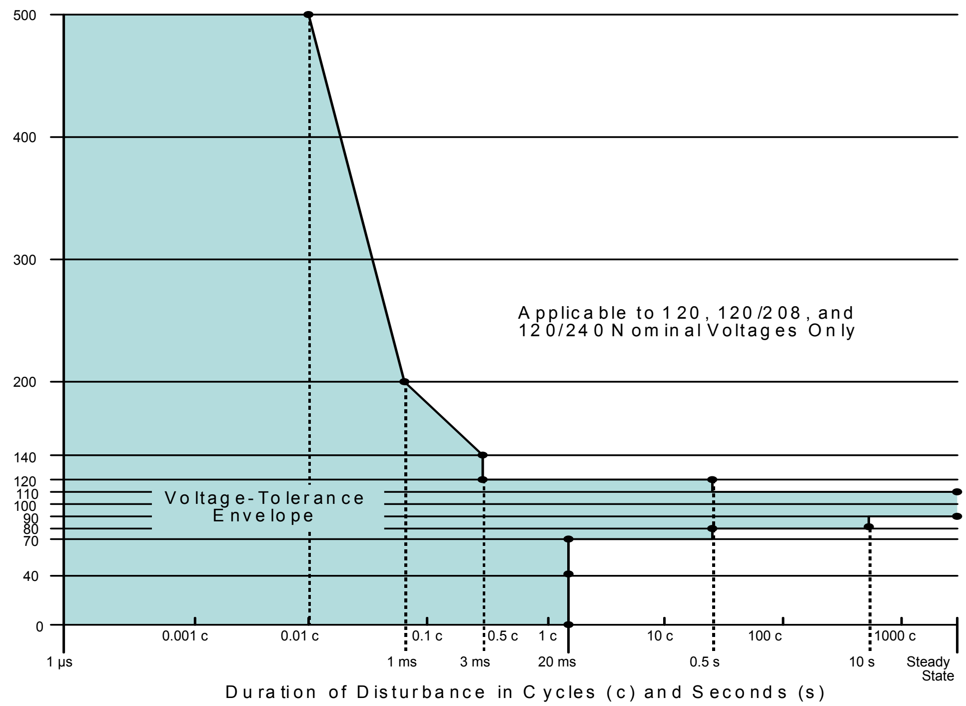


Figure 3-5
ITIC (CBEMA 96) Curve

The ITIC/CBEMA 96 curve is a revision to the earlier CBEMA curve which has been used as an equipment benchmark for power supplies since the late 1970s and further adopted as a voltage sag ride-through benchmark for comparison to equipment immunity. Although the ITIC curve provides a useful line in the sand for comparison, equipment designed to this standard can still be susceptible to common voltage sags. This may be due in part to the fact that the standard is based on average case power supply ride-through characteristics rather than the optimal power supply performance to match the electrical environment. The semiconductor manufacturing community recently came to the realization that the ITIC curve was not correct for their industry. By gathering voltage sag data from fifteen semiconductor manufacturing facilities representing 30.5 monitor years of data and 1,076 events, it became clearer to ascertain what level of immunity was needed from the equipment (Figure 3-6).

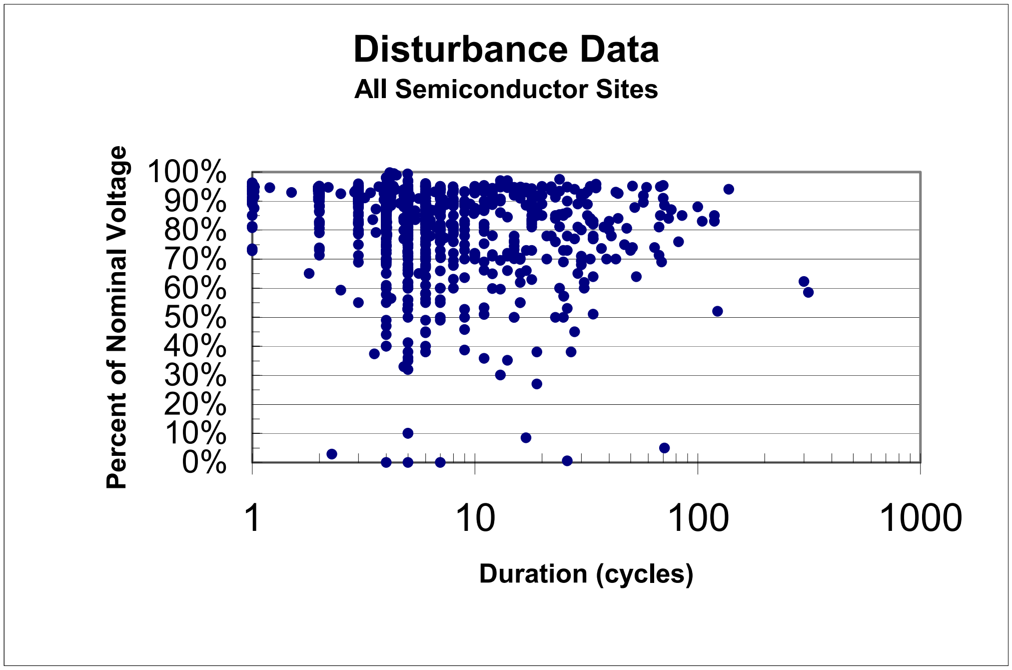


Figure 3-6
Scatter Plot of Voltage Sag Data Used in SEMI F47 Standard

The new standard, titled SEMI F47 "Specification for Semiconductor Processing Equipment Voltage Sag Immunity", is shown in Figure 3-7. The SEMI F47 standard defines the voltage sag tolerance expected from semiconductor tooling equipment. Data from the semi study indicated that fluctuations caused by disturbances on the electrical distribution system can be as severe as an outage, but over 90 percent of the events seen at the studied semiconductor sites were above 50 percent of nominal voltage, with the most occurrences between 3 to 7 cycles in duration. Furthermore, the total number of events on or below the ITIC/CBEMA '96 curve was 166. Thirteen of the fifteen semiconductor sites averaged at least one event below the CBEMA '96 each year. The average number of occurrences below CBEMA 96', per site, each year was approximately 5.4. Using the SEMI F47 curve, it was found that out of the total population of disturbances, only 8.8 percent (86 events) were below the curve, which is a 42 percent improvement over the CBEMA '96 curve. The average number of events below the curve per site per year also dropped to 3.1. Based on research on immunity of components that make up semiconductor tooling equipment, this standard is attainable through the use of better relays, power supplies, and design schemes.

The specification simply states that Semiconductor processing, metrology, and automated test equipment must be designed and built to conform to the voltage sag ride-through capability per the defined curve. Equipment must continue to operate without interrupt (per SEMI E10 - Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability) during conditions identified in the area above the defined line. In the context of SEMI E-10, interrupt means any assist or failure. An assist is defined as an unplanned interruption that occurs during an equipment cycle where all three of the following conditions apply:

- The interrupted equipment cycle is resumed through external intervention (e.g., by an operator or user, either human or host computer).
- There is no replacement of a part, other than specified consumables.
- There is no further variation from specification of equipment operation.

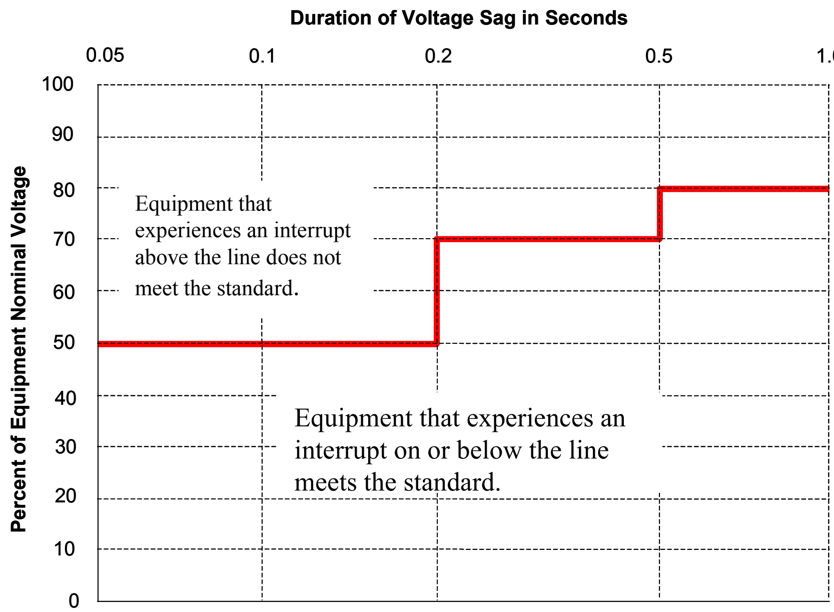


Figure 3-7
SEMI F47 Curve

Furthermore, a failure is any unplanned interruption or variance from the specifications of equipment operation other than assists. Although no variation in the tool's process is the goal, this standard addresses these issues as related to the equipment operation only.

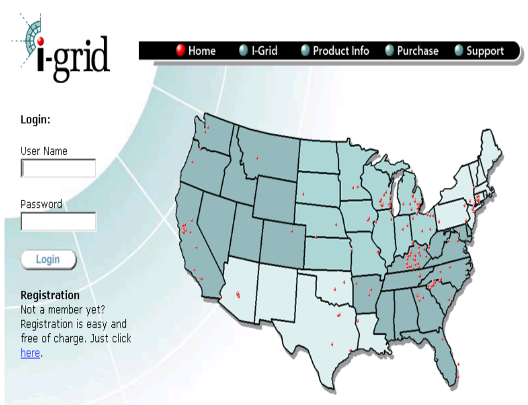
In order for the food processing industry to reduce the number of voltage sag related process interruptions, a similar food processing standard should be implemented. Unless a standard is put in place, there will be no movement equipment suppliers and system integrators to improve power quality robustness of their designs. There is an existing database of basic types of control components such as PLCs, power supplies, relays, contactors, motor starters, ASDs, and servo systems that are compliant with SEMI F47. The SEMI F47 curve could be applied to the food processing industry as a power quality standard or a new curve could be developed just for food processing. The beauty of adopting an existing power quality standard is that a database of compliant devices and design techniques is already in existence. Therefore, system integrators and engineers would have an existing set of robust approaches available.

3.4 Del Monte Historical Power Quality Data

In the course of this project, EPRI PEAC worked with Del Monte to install power quality monitors at both the Modesto facility as well as the Kingsburg plant. Data from both plants will be presented here.

For both facilities, the I-Grid power quality monitoring system was used. Developed by Softswitching Technologies, the I-Grid utilizes low-cost voltage-only monitors that cost from $195 per unit for single-phase monitoring to $295 per unit for three-phase monitoring. The I-specifications for the I-Grid system and I-sense power quality monitor and specifications are shown in Table 3-3.

Table 3-3
I-Grid/I-Sense Specifications



Web-Based I-Grid Monitoring System

I-Grid™ System Event Display Specifications:

User Interface	Web browser via I-Grid.com website with geographic monitor place
Event Display	Time stamp, RMS voltage profile & voltage waveforms per phase For sustained interruptions, only first minute of RMS voltage data and end time of event are displayed Magnitude-Duration plots of user selected events Display events against ITIC and SEMI F47 standards
Waveform Characteristics	32 points per cycle displayed, up to 3 phases Maximum 8 cycles capability (from –1 to +3 cycles at start of event, and –3 to +1 cycles at end of event)
Event Characterization	Per IEEE 1159.1 sags, swells, under-voltages, over-voltages, interruptions
Time Stamp Reference	Based on SNTP Time Protocol Synchronized to GMT (NIST reference) Individual I-Sense monitors synchronized to +/- 0.1 seconds
Event Storage Capacity	>10,000 events for each I-Sense monitor

I-Grid Account Management:

User Interface	Web browser via I-Grid.com website
Event Notification	User configurable email or pager* notification
Event Severity Discriminator	User configurable event reporting*
Event Reporting Response	Typically 90 to 120 seconds
I-Sense Unit Management	User configurable for I-Sense monitor dial-out schedule and local ISP phone number (ISP provided by SoftSwitching)
Data Mining and Reports	See website for free data processing and reporting functions (Contact SoftSwitching for additional needs)

I-Sense Monitor

I-Sense™ Monitor Specifications:

Voltage Ratings

Model	Phase	Volts	Hertz
V1120A00	Single	120 volts	60
V3120A00	Three	208 (L-L) 120 (L-N)	60
V3480A00	Three	480 (L-L)	60

Input Voltage Range	0 to 120% of nominal voltage
Accuracy of Measurement	Typically +/- 0.2% of full scale Maximum +/- 1% of full scale True RMS computation
Sampling Rate	32 times per cycle for each phase (3X oversampling)
Event Detection Criteria	RMS voltage deviation < 87% or > 115% of nominal Adaptive wave shape deviation algorithm
Data Logging	Non-volatile memory event storage ○ Up to 200 events for single phase units ○ Up to 70 events for three phase units Periodic min/max RMS voltage data over user-selected periods User configurable event dial-up criteria
Protocols	V.32bis (14,400 bps) / V.42 Error Correction HTTP, TCP/IP, PPP, XML Shared touch-tone analog telephone line compatible Recommend maximum of three shared units per telephone line Currently available for use in USA
User Interface	LED/Button
Internal Battery	Rechargeable, long life, 9 volt Enables dial-up on sustained power interruption
Temperature Range	0° C to 45° C
Certification	UL, FCC, CSA, CE, ICES
Diagnostics	Flashing LED for response/event notification

The type of monitor and location installed at each plant is shown in Table 3-4.

Table 3-4
I-Sense Monitor Installations at Del Monte

Unit	Plant	Location	Voltage Measurement	Note
1	Modesto	Building 6 Boiler Room 120Vac Outlet	120Vac, Single-Phase	Functional 6/6/02
2	Modesto	Building 8 3-Phase Power	480Vac, Three-Phase	Functional 6/7/02
3	Kingsburg	Boiler Room Control Power	120Vac, Single-Phase	Functional 9/17/02
4	Kingsburg	Cannery Control Power	120Vac, Single-Phase	Functional 9/17/02

The power quality data event data recorded for each monitor is listed in Tables 3-5 through 3-8. This data was gathered by the I-Grid system and formatted for use within this report. The tables contain the following fields

1. **No.** This is the sequential event number as designated by EPRI PEAC for purposes of organizing each table.

2. **ID.** This is the event ID number as assigned by the I-Grid system. Each event ID contains a hyperlink to the event at the I-Grid web site. If you click on the event, you will asked to enter the username and password and then you can view the particular event data.

3. **Local Time.** This is the date and time stamp for each recorded event. The time is given in military time format.

4. **Event Type.** The event type is a event description based on the IEEE-1159 standard as described in Section 3.1 of this report.

5. **Duration (cycles).** This is the duration, in cycles, of the power quality event that was recorded. Each 60Hz cycle is equivalent to 16.67 milliseconds.

6. **Sag % Nominal RMS.** This is percent magnitude of the recorded power quality event with respect to the nominal voltage prior to the event. This value is usually less than the rated value of the circuit. Based on the utility or plant electrical loading, the nominal voltage can be significantly lower than the rated voltage. For example, the nominal voltage prior to a voltage sag of 107Vac was measured by the I-Sense installed at the Kingsburg boiler. The rated voltage of this circuit is 120Vac. Therefore, the low nominal voltage will affect the ability of the system to ride-through minor voltage sags.

7. **Sag % Rated RMS.** This is the percent magnitude of the recorded power quality event with respect to the rated voltage that is to be supplied to the load (i.e. 120Vac or 480Vac) This value is very important in that EPRI PEAC's knowledgebase of known equipment

susceptibilities is based on testing against rated voltage. Furthermore, equipment is typically vulnerable at a particular voltage value, not a percentage. For example the Allen Bradley PLC-5 is vulnerable to 78% of rated (voltage drops below 94 Vac) voltage sags, lasting two cycles or more. However, if the nominal voltage in the plant is 107Vac, then the PLC will be more susceptible to voltage sags, dropping out at when the voltage dips to only 87% of nominal.

8. **Delta (Nom to Rated).** This value represents the difference between the rated voltage and nominal voltage during a voltage sag. In some cases, the Del Monte PQ data shows that the percentage of nominal voltage is as much as 13 percent lower than the percent of rated during the voltage sag. Therefore, as viewed by the load device, the voltage sag is more severe than first appears.

9. **Expect Effect on Process?** Based on the comparison to the depth of the voltage sag with respect to the % rated value, EPRI PEAC has assigned three outcomes for this question for every event.

    a. **Yes** – This is assigned as the expected outcome when the Sag % Rated RMS value is less than 80% of nominal. All events that are expected to cause a process upset are shown in bold in the following tables.

    b. **Possible** – This is assigned as the expected outcome when the Sag % Rated RMS value is from 80% to 85% of rated. All events that are expected to possible cause a process upset are shown in italics in the following tables.

    c. **No.** This is assigned as the expected outcome when the Sag % Rated RMS value is greater than 85% and less than 110%.

Table 3-5
Del Monte Modesto Building 6 PQ Events (6/6/02-11/17/02)

No.	***ID***	***Local Time***	***Event Type****	***Duration (cycles)***	***Sag % Nominal RMS***	***Sag % Rated RMS***	***Delta (Nom to Rated)***	***Expect Effect On Process?***
1	**934**	**7/12/2002 14:33**	**Sustained Interruption**	**250161**	**0%**	**0%**	**0%**	**Yes**
2	1679	8/29/2002 13:52	Instantaneous Sag	1.1	99%	86%	-13%	No
3	1857	9/6/2002 14:42	Instantaneous Sag	1.8	99%	86%	-13%	No
4	2221	9/25/2002 11:55	Instantaneous Sag	1.7	99%	86%	-13%	No
5	2225	9/25/2002 11:55	Instantaneous Sag	1.5	99%	86%	-13%	No
6	2226	9/25/2002 11:55	Instantaneous Sag	2.8	99%	86%	-13%	No
7	*2266*	*9/27/2002 4:04*	*Instantaneous Sag*	*9.8*	*90%*	*81%*	*-9%*	*Possible*
8	2459	10/11/2002 18:45	Transient	0.5	100%	94%	-6%	No
9	2469	10/12/2002 6:56	Transient	0.5	99%	95%	-5%	No
10	*2623*	*10/23/2002 6:09*	*Instantaneous Sag*	*5.6*	*89%*	*83%*	*-6%*	*Possible*
11	2789	11/5/2002 0:55	Transient	0.6	100%	95%	-5%	No
12	**2822**	**11/7/2002 3:06**	**Instantaneous Sag**	**18.5**	**81%**	**77%**	**-3%**	**Yes**
13	**2823**	**11/7/2002 3:06**	**Instantaneous Sag**	**15.2**	**75%**	**72%**	**-3%**	**Yes**
14	2829	11/7/2002 10:19	Transient	0.5	100%	97%	-3%	No
15	*2840*	*11/7/2002 14:05*	*Instantaneous Sag*	*1*	*90%*	*84%*	*-6%*	*Possible*
16	2849	11/7/2002 16:04	Transient	0.6	100%	96%	-3%	No
17	*2854*	*11/7/2002 20:41*	*Instantaneous Sag*	*0.8*	*82%*	*80%*	*-2%*	*Possible*
18	*2858*	*11/7/2002 23:41*	*Instantaneous Sag*	*1.9*	*97%*	*85%*	*-12%*	*Possible*
19	*2868*	*11/8/2002 8:12*	*Instantaneous Sag*	*0.8*	*88%*	*83%*	*-5%*	*Possible*
20	2902	11/10/2002 4:08	Transient	0.5	100%	95%	-5%	No
21	**2984**	**11/16/2002 11:50**	**Instantaneous Sag**	**5.9**	**83%**	**79%**	**-4%**	**Yes**

Table 3-6
Del Monte Modesto Building 8 PQ Events (6/7/02-11/17/02)

NO.	ID	Local Time	Event Type*	Duration (cycles)	Sag % Nominal RMS	Sag % Rated RMS	Delta (Nom to Rated)	Expect Effect On Process?
1	***1481***	**7/15/2002 12:56**	**Temporary Interruption**	**3512.7**	**0%**	**0%**	**0%**	**Yes**
2	***2243***	**9/3/2002 6:26**	**Sustained Deep Undervoltage**	**580058**	**73%**	**68%**	**-5%**	**Yes**
3	*2560*	*9/27/2002 4:04*	*Instantaneous Sag*	*6*	*92%*	*85%*	*-7%*	*Possible*
4	*2750*	10/10/2002 18:25	Transient	0.5	99%	97%	-2%	No
5	*2769*	10/11/2002 19:03	Transient	0.5	99%	98%	-2%	No
6	*2785*	10/12/2002 19:43	Transient	0.6	99%	98%	-1%	No
7	*2864*	10/17/2002 11:51	Transient	0.5	99%	98%	-1%	No
8	*2929*	10/21/2002 18:36	Transient	0.5	99%	98%	-1%	No
9	*2938*	10/21/2002 21:40	Transient	0.5	99%	98%	0%	No
10	*2956*	10/23/2002 6:09	Instantaneous Sag	6.5	86%	84%	-2%	Possible
11	*3004*	10/26/2002 17:31	Transient	0.6	99%	98%	-1%	No
12	*3019*	10/27/2002 9:54	Transient	0.6	99%	96%	-3%	No
13	*3031*	10/28/2002 7:19	Transient	0.5	99%	98%	-1%	No
14	*3041*	10/28/2002 20:12	Transient	0.5	99%	98%	-1%	No
15	*3077*	10/31/2002 8:08	Transient	0.5	99%	98%	-1%	No
16	*3086*	*10/31/2002 13:00*	*Instantaneous Sag*	*6.5*	*88%*	*86%*	*-1%*	*Possible*
17	*3103*	11/1/2002 18:54	Transient	0.5	99%	98%	-1%	No
18	*3120*	11/2/2002 18:03	Transient	0.5	100%	97%	-3%	No
19	*3186*	*11/7/2002 3:01*	*Instantaneous Sag*	*2.9*	*83%*	*82%*	*-1%*	*Possible*
20	***3190***	**11/7/2002 3:06**	**Instantaneous Sag**	**18.6**	**79%**	**79%**	**0%**	**Yes***
21	***3191***	**11/7/2002 3:06**	**Instantaneous Sag**	**15.2**	**75%**	**75%**	**0%**	**Yes***
22	*3201*	*11/7/2002 10:19*	*Instantaneous Sag*	*1.6*	*86%*	*84%*	*-1%*	*Possible*
23	*3205*	11/7/2002 14:05	Instantaneous Sag	0.8	92%	87%	-4%	No
24	*3215*	*11/7/2002 20:41*	*Instantaneous Sag*	*1*	*83%*	*83%*	*0%*	*Possible*
25	*3219*	*11/7/2002 20:50*	*Instantaneous Sag*	*2*	*86%*	*84%*	*-2%*	*Possible*
26	*3229*	11/8/2002 8:12	Instantaneous Sag	0.8	84%	84%	0%	No
27	*3244*	11/9/2002 1:22	Transient	0.5	102%	102%	0%	No
28	*3254*	11/9/2002 14:01	Transient	0.6	102%	102%	0%	No
29	*3312*	11/13/2002 5:41	Transient	0.5	103%	102%	0%	No

Table 3-7
Del Monte Kingsburg Boiler PQ Events (9/17/02-11/17/02)

No.	ID	Local Time	Event Type*	Duration (cycles)	Sag % Nominal RMS	Sag % Rated RMS	Delta (Nom to Rated)	Expect Effect on Process
1	272	9/24/2002 11:28	Instantaneous Sag	4.4	96%	86%	-10%	No
2	**371**	**9/26/2002 11:36**	**Instantaneous Sag**	**14.1**	**73%**	**70%**	**-3%**	**Yes**
3	**550**	**9/30/2002 11:44**	**Temporary Interruption**	**1981**	**0%**	**0%**	**0%**	**Yes**
4	**644**	**10/2/2002 7:12**	**Temporary Interruption**	**335.3**	**0%**	**0%**	**0%**	**Yes- Note 1**
5	**653**	**10/2/2002 7:13**	**Momentary Interruption**	**107.4**	**0%**	**0%**	**0%**	**Yes - Note 1**
6	**654**	**10/2/2002 7:13**	**Momentary Interruption**	**137.5**	**0%**	**0%**	**0%**	**Yes - Note 1**
7	**892**	**10/8/2002 9:03**	**Instantaneous Interruption**	**2.8**	**4%**	**4%**	**0%**	**Yes**
8	937	10/8/2002 18:35	Transient	0.5	105%	104%	-1%	No
9	979	10/9/2002 18:35	Transient	0.5	105%	103%	-2%	No
10	1012	10/10/2002 7:17	Momentary Sag	69.6	86%	82%	-4%	Possible
11	**1013**	**10/10/2002 7:17**	**Instantaneous Sag**	**29.4**	**76%**	**76%**	**0%**	**Yes**
12	1014	10/10/2002 7:17	Transient	0.5	95%	96%	1%	No
13	1147	10/14/2002 12:17	Transient	0.5	100%	98%	-2%	No
14	1296	10/18/2002 18:34	Transient	0.5	106%	105%	-1%	No
15	1336	10/19/2002 18:34	Transient	0.5	106%	105%	-1%	No
16	1379	10/20/2002 18:35	Transient	0.6	105%	104%	-1%	No
17	1405	10/21/2002 5:27	Instantaneous Sag	12.2	92%	83%	-10%	Possible
18	1429	10/21/2002 18:35	Transient	0.5	104%	104%	0%	No
19	1452	10/22/2002 8:43	Transient	0.4	100%	98%	-2%	No
20	**1569**	**10/23/2002 10:40**	**Temporary Interruption**	**250**	**0%**	**0%**	**0%**	**Yes**
21	1655	10/25/2002 18:34	Transient	0.5	106%	105%	0%	No
22	1710	10/27/2002 5:18	Instantaneous Sag	15.5	99%	89%	-10%	No

Table 3-7 (Continued)
Del Monte Kingsburg Boiler PQ Events (9/17/02-11/17/02) (Continued)

No.	ID	Local Time	Event Type*	Duration (cycles)	Sag % Nominal RMS	Sag % Rated RMS	Delta (Nom to Rated)	Expect Effect on Process
23	1767	10/28/2002 16:11	Transient	0.6	102%	102%	0%	No
24	2061	11/7/2002 7:37	Momentary Sag	52.3	89%	85%	-4%	Possible
25	**2073**	**11/7/2002 9:45**	**Instantaneous Sag**	**15.6**	**64%**	**61%**	**-3%**	**Yes**
26	2074	11/7/2002 9:45	Instantaneous Sag	10	88%	87%	-1%	No
27	2087	11/7/2002 10:20	Instantaneous Sag	3.8	99%	89%	-10%	No
28	**2099**	**11/7/2002 10:42**	**Instantaneous Sag**	**20.2**	**45%**	**44%**	**-1%**	**Yes**
29	**2111**	**11/7/2002 10:50**	**Temporary Interruption**	**607.2**	**0%**	**0%**	**0%**	**Yes**
30	2112	11/7/2002 10:51	Instantaneous Sag	1	87%	87%	1%	No
31	2252	11/11/2002 15:02	Instantaneous Sag	16.4	85%	84%	-1%	Possible
32	2382	11/15/2002 17:33	Transient	0.5	107%	107%	-1%	No
33	2459	11/17/2002 17:33	Transient	0.5	105%	105%	0%	No

Table 3-8
Del Monte Kingsburg Cannery PQ Events (9/17/02-11/17/02)

No.	ID	Local Time	Event Type*	Duration (cycles)	Sag % Nominal RMS	Sag % Rated RMS	Delta (Nom to Rated)	Expect Effect On Process?
1	**60**	**9/18/2002 7:00**	**Sustained Interruption**	**20692.7**	**0%**	**0%**	**0%**	**Yes- Note 2**
2	**78**	**9/18/2002 7:06**	**Momentary Interruption**	**137.9**	**0%**	**0%**	**0%**	**Yes – Note 2**
3	*404*	*9/26/2002 11:36*	*Instantaneous Sag*	*12.8*	*91%*	*84%*	*-8%*	*Possible*
4	*958*	*10/10/2002 7:17*	*Momentary Sag*	*36*	*91%*	*82%*	*-8%*	*Possible*
5	**960**	**10/10/2002 7:17**	**Instantaneous Sag**	**29.4**	**74%**	**76%**	**2%**	**Yes**
6	966	10/10/2002 7:17	Transient	0.5	91%	93%	2%	No
7	1021	10/11/2002 14:32	Transient	0.5	102%	101%	-1%	No
8	1294	10/19/2002 18:34	Transient	0.5	105%	106%	0%	No
9	*1345*	*10/21/2002 5:27*	*Instantaneous Sag*	*13.9*	*86%*	*83%*	*-3%*	*Possible*
10	1399	10/22/2002 18:35	Transient	0.6	103%	103%	0%	No
11	1538	10/27/2002 5:18	Transient	0.5	100%	91%	-9%	No
12	1595	10/28/2002 10:02	Transient	0.5	100%	97%	-3%	No
13	1609	10/28/2002 14:01	Transient	0.5	102%	102%	0%	No
14	1923	11/7/2002 7:37	Momentary Sag	36.5	99%	88%	-11%	No
15	**1937**	**11/7/2002 9:45**	**Instantaneous Sag**	**16**	**65%**	**63%**	**-2%**	**Yes**
16	1938	11/7/2002 9:45	Transient	0.5	100%	91%	-9%	No
17	**1949**	**11/7/2002 10:42**	**Instantaneous Interruption**	**9.7**	**6%**	**6%**	**-1%**	**Yes**
18	**1961**	**11/7/2002 10:50**	**Temporary Interruption**	**639.6**	**0%**	**0%**	**0%**	**Yes**
19	**1965**	**11/7/2002 10:51**	**Sustained Interruption**	**677597.4**	**0%**	**0%**	**0%**	**Yes**
20	2012	11/7/2002 19:28	Transient	0.5	100%	96%	-4%	No
21	2025	11/8/2002 1:02	Transient	0.5	91%	88%	-3%	No
22	2026	11/8/2002 1:02	Transient	0.5	102%	102%	1%	No
23	4492	11/12/2002 16:43	Transient	0.5	103%	102%	-1%	No
24	4505	11/12/2002 17:33	Transient	0.5	105%	105%	0%	No
25	4548	11/13/2002 17:33	Transient	0.5	100%	99%	-1%	No
26	4622	11/15/2002 17:33	Transient	0.5	105%	105%	1%	No

Note 1: These three interruptions occurred within the same minute. Therefore, they should be considered a single power quality event and counted as a single interruption.

Note 2: These two interruptions are believed to have occurred during hookup of the power quality monitor at the Kingsburg Cannery location. Therefore, it is questionable as to whether they should be considered actual power quality events.

November 7th, 2002 was a day in which both the Modesto and Kingsburg monitors reported multiple power quality events. Utilizing the resources available on the Internet, the weatherchannel.com site shows how torrential rains were moving through the area such that both plants were covered at essentially the same time. If this has occurred during production season, Del Monte would experience a significant impact with the Modesto, Kingsburg, and possibly the Hanford plant shutting down due to weather related voltage sag induced events. Figure 3-8 shows the storm track at 1:14 eastern standard time. This weather system was responsible for twenty-eight power quality events as recorded at the two plants on November 7th, 2002. Historically, the type of weather that occurred on November 7th does happen more often in the spring and fall in this region of California. Rain is rare in central California during the summer production months of July, August, and September. When rain does come during the summer, Del Monte has noted that power quality problems always occur.

Figure 3-8
Weather System Affecting Del Monte Plants on November 7th, 2002

In order to measure the quality of power supplied to a site, it is possible to use the System Average RMS (Variation) Frequency Index or SARFI. The SARFI measurement is one of the metrics used by utilities to gage the performance of their electrical system. The higher the SARFI number, the more events occurred within the specified range. Ideally, the utility would strive to minimize the SARFI values for a given site. “SARFIx” represents the average number of specified rms variation measurement events that occurred over the assessment period per customer served, where the specified disturbances are those with a magnitude of less than x for sags or greater than x for swells. For the purposes of this study, these indices will be used to calculate SARFI for sag event data only. For example, SARFI $_{50}$ will produce the average number of voltage sags that occurred over the assessment period that were below 50% of nominal or rated voltage. For the purposes of this report, all SARFI numbers are calculated with respect to rated voltage of the load devices (i.e. 120Vac or 480Vac). Furthermore, extending the same concept to evaluate the number of events that would occur below a voltage sag standard curve such as SEMI F47 or the ITIC curve, indices such as $SARFI_{SEMI\ F47}$ and $SARFI_{ITIC}$ can be calculated as well.

Table 3-9 contains the summary data for all power quality events recorded by the I-Grid monitoring system monitors at both the Modesto and Kingsburg sites. In addition to the SARFI data, other statistics are presented such as the number of sags and interruptions recorded and the sag to interruption ratio. Both of the Modesto monitors recorded sag to interruption ratios that were better than the national average. Likewise, both Kingsburg monitors recorded ratios that were worse than the national average. Also shown in the data are statistics concerning average and median voltage sag depths and durations.

Table 3-9
Power Quality Data Summary for Del Monte Modesto and Kingsburg Sites
(One Minute Temporal Aggregation Used)

SITE	Modesto Bldg 6	Modesto Bldg 8	Kingsburg Cannery	Kingsburg Boiler	National Average (from DPQ)
Monitoring Period	6/6/02-11/17/02	6/6/02-11/17/02	9/17/02-11/17/02	9/17/02-11/17/02	
SARFI $_{10}$	1	1	4	6	
SARFI $_{50}$	1	1	4	7	
SARFI $_{70}$	1	2	5	8	
SARFI $_{80}$	3	3	6	10	
SARFI $_{90}$	12	12	10	18	
SARFI $_{SEMI\ F47}$	1	2	8	7	
SARFI $_{ITIC}$	1	2	7	7	
Number of Voltage Sags	11	10	7	12	9.8
Number of Interruptions	1	1	4	6	1
Sag/Interruption Ratio	11.0	10.0	1.8	2.0	9.8
Average Sag Magnitude	82%	84%	68%	72%	
Average Sag Duration (Cycles)	4.2	4.3	21	19.6	
Median Sag Magnitude	83%	84%	83%	84%	
Median Sag Duration (Cycles)	1.9	2.5	22.70	15.6	

Finally, Figure 3-9 shows the number of recorded power quality events per month for each monitor location. Also shown on the X-Axis of the graph is the seasonal production run (July 1st through October 1st). In the case of the Modesto plant, most of the power quality problems occurred after the completion of the seasonal peach production. If the same frequency of events occurred during the summer months, it is expected that the plant would have experienced significant production impact due to the events. It is also important to note that the Kingsburg monitors were not installed until September 17th.

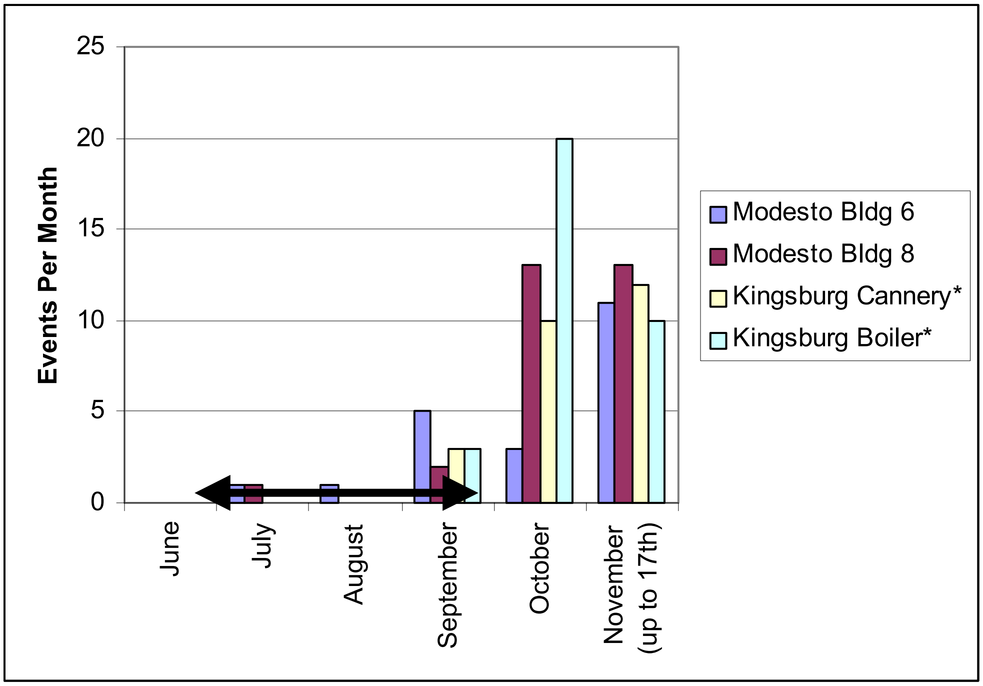


Figure 3-9
Frequency of Recorded Power Quality Events Per Site Per Month with Production Season Overlaid

**Note: Kingsburg Monitors were not installed until September 17th 2002.*

4

EQUIPMENT ANALYSIS AND GENERAL RECOMMENDATIONS

4.1 Review of General Findings from EPRI Research

EPRI PEAC Corporation has conducted thousands of tests on electrical equipment since the early 1990s. Furthermore, EPRI PEAC Corporation has performed hundreds of power quality studies and audits for industrial customers. From this wealth of test information, EPRI research has concluded that most industrial processes are negatively impacted by voltage sag type power quality events. Furthermore, research has shown the types of subsystem components that are susceptible and to what extent they are vulnerable. A portion of the findings that are relevant to the food processing industry are presented here.

4.1.1 AC Powered Relays, Contactors, and Motor Starters

These electromechanical devices are used extensively in process control systems. Relays are typically used as logic elements to switch control circuits, large starter coils, and light electrical loads. Contactors are electro-magnetically operated switches that provide a safe and convenient means for connecting and interrupting power circuits. Motor Starters basically have the same function as contactors but they also provide over current protection for the motor.

Figure 4-1
From Left to Right - "Ice Cube" Relay, Contactor, Motor Starter

Figure 4-2 shows the typical voltage sag ride-through curves for these devices. Also shown on the graph is the scatter plot of power quality events from the four monitoring locations.

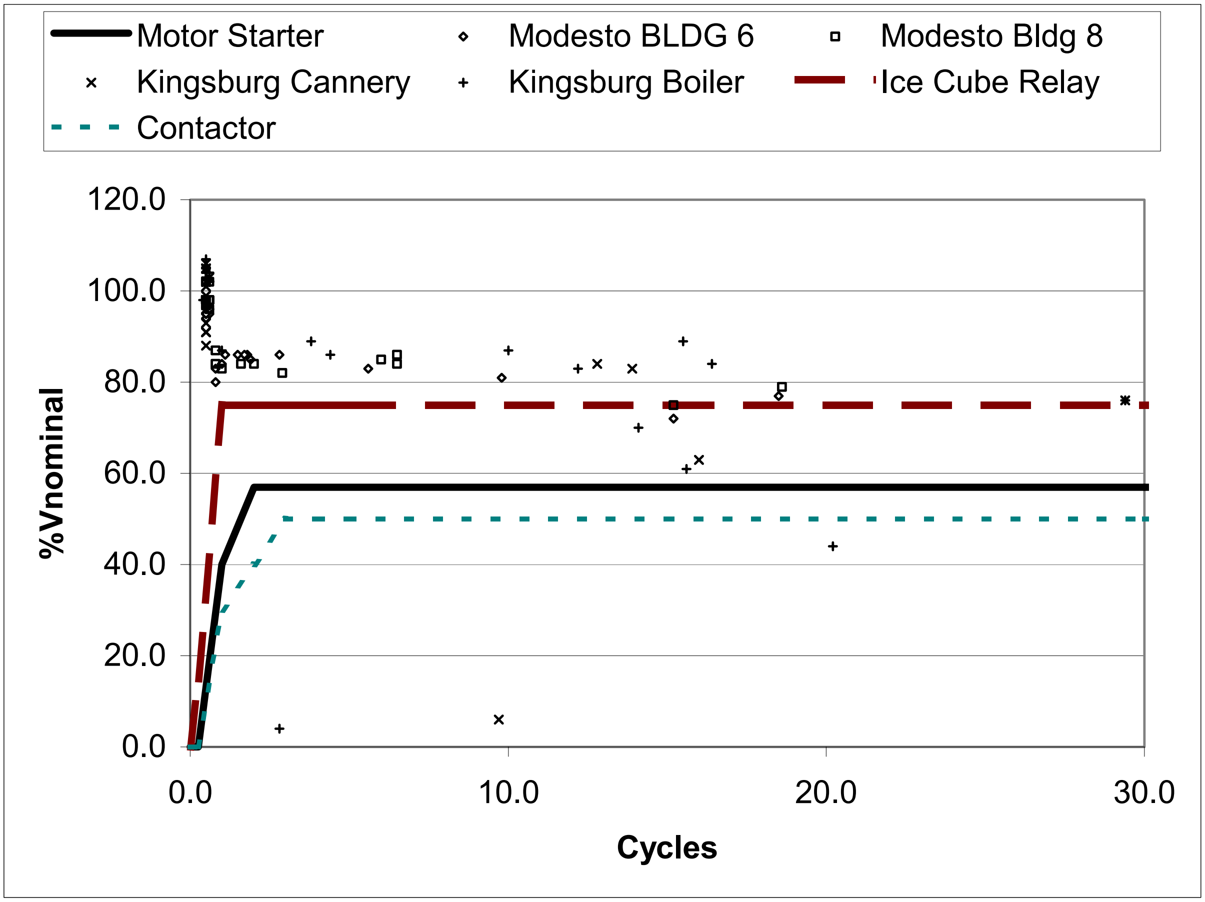


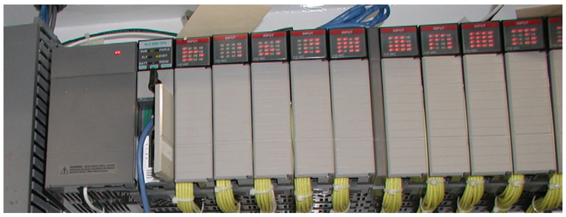
Figure 4-2
Typical Voltage Sag Ride-Through Curves for Relays, Contactors, and Motor Starters as compared with Power Quality Data from the Modesto and Kingsburg plants

Note: Sustained outage data not shown on this scale.

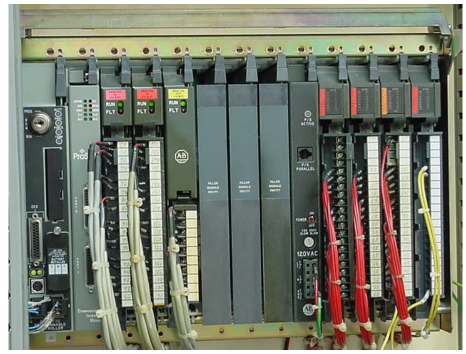
From Figure 4-2, one can see that eight of the recorded voltage sag and short duration outage events would be likely to trip control systems that utilize “ice cube” relays. Likewise, three events recorded from the Kingsburg dataset would likely trip out motor control and contactor circuits.

4.1.2 Programmable Logic Controllers

Programmable logic controllers (PLCs) are the backbone of industrial automation. PLCs are used extensively in food processing in order to control automated processes. Del Monte utilizes Allen Bradley SLC-5/x controllers as well as Allen Bradley PLC-5 systems at the Modesto facility. These systems utilize sensitive AC powered I/O (sensors and motor controls,etc.). Responding in less than 16 milliseconds (1 60 hz cycle), AC Discrete Input points on PLC systems are very responsive to detecting when voltage drops to a given “threshold” level. For this reason, the immunity of the PLC and the AC Discrete Input channels are important to consider when determining voltage sag ride-through. The Allen Bradley PLC-5 and SLC-5/x series PLCs are shown in Figure 4-3.



AB SLC-5/x PLC with
1746-P1 AC Input Power Supply



AB PLC-5 System with
1771-P4S AC Input Power Supply

Figure 4-3
Allen Bradley PLC Hardware Used by Del Monte

The voltage sag ride-through curves for these two AB PLC systems is presented in Figures 4-4 and Figures 4-5. As before, a scatter plot of power quality data from the Modesto and Kingsburg plants are included for comparison. It is important to note that the ride-through of the AB PLC-5 system is based on using either the 1771-P4S or 1771-P7 AC input power supply modules.

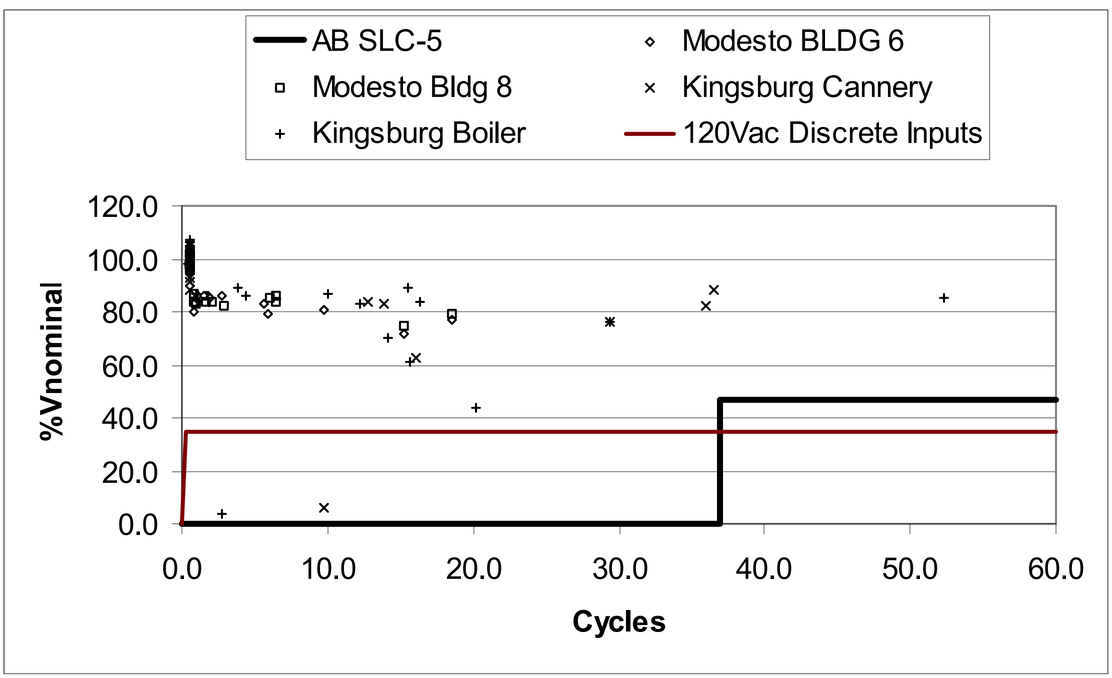


Figure 4-4
AB SLC-5/x with AC Discrete Input Module Voltage Sag Ride-Through as compared with Power Quality Data from the Modesto and Kingsburg plants

Note: Sustained outage data not shown on this scale.

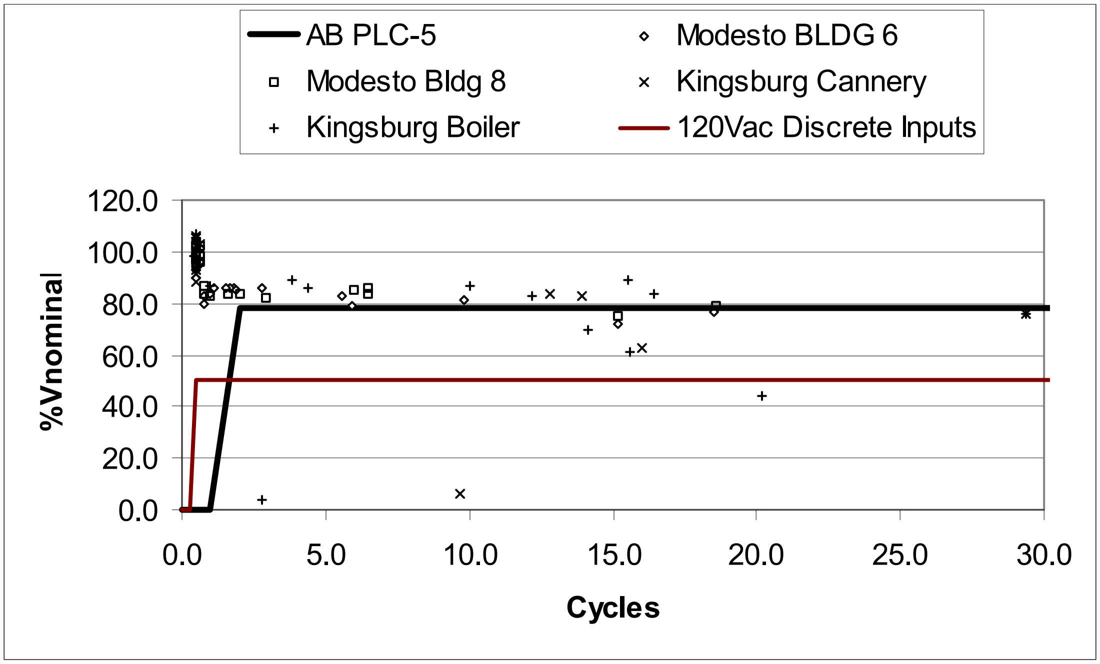
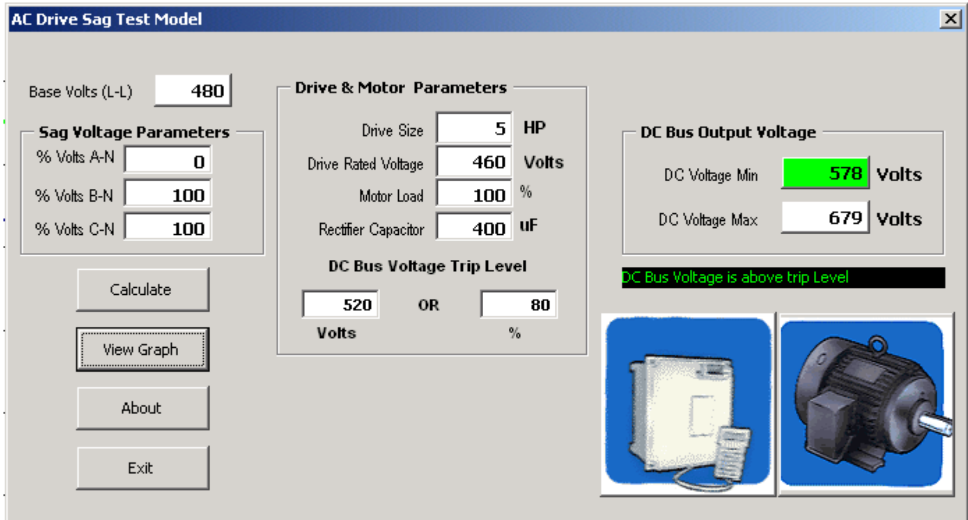


Figure 4-5
AB PLC-5 with AC Discrete Input Module Voltage Sag Ride-Through as compared with Power Quality Data from the Modesto and Kingsburg plants

Note: Sustained outage data not shown on this scale.

4.1.3 Adjustable Speed Drives

AC inverter drives, often referred to as Adjustable Speed Drives (ASDs) are used by Del Monte in various process applications with drive sizes ranging from a few horsepower to the 75 horsepower range. Typically, ASDs are not susceptible to single-phase voltage sags. In fact, many units tested by EPRI PEAC show that the units can withstand an outage on a single-phase lasting up to one second or more and continue operating. This is possible because the DC bus trip point is typically not reached when a single-phase drops out. Basically, the other two remaining phases are able to provide the “peak” charge voltage needed to keep the drive above the trip level. Figure 4-6 shows the typical drive DC bus output when a single-phase drops to zero volts while the remaining phases are left at 100 percent of nominal. This output is modeled for a 5 horsepower drive, loaded to 100 percent, with an 80 percent of nominal DC bus trip level.



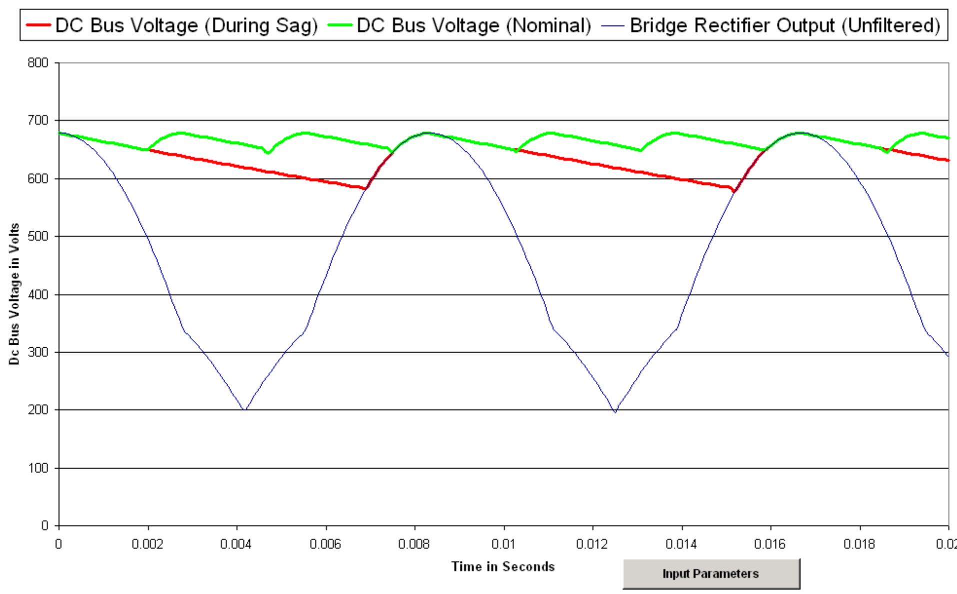


Figure 4-6
AC Inverter Drive Model Output For Single-Phase Outage (No Shutdown)

Two-phase voltage sags are detrimental to ASDs in that they can cause a DC bus undervoltage and lead the drive trip off-line during a power quality event. Figure 4-7 shows the model input parameters and DC bus output for a two-phase sag. All other drive parameter settings are the same as in the example shown in Figure 4-6. The drive model shows that for two-phase sags of 70 percent of nominal or less, this drive will shutdown as a result of low DC bus voltage.

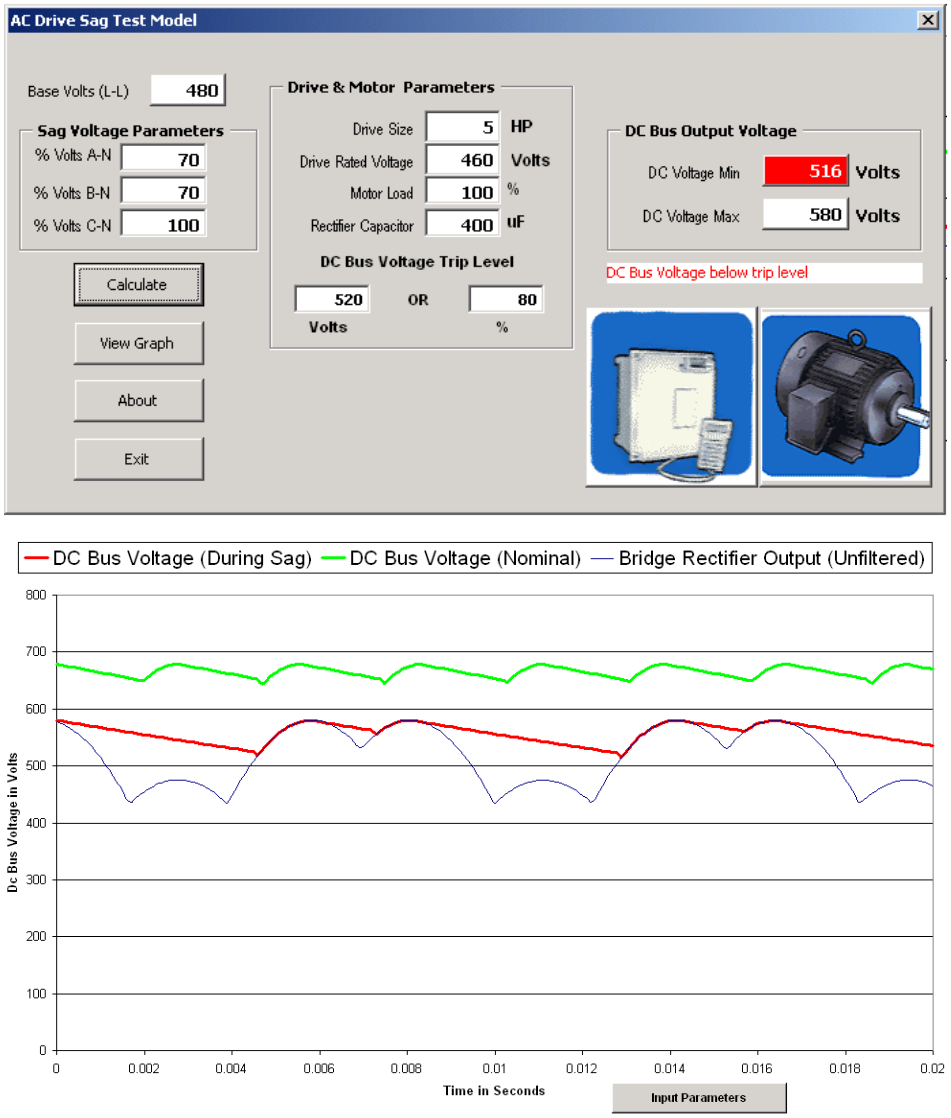


Figure 4-7
AC Inverter Drive Model Output For Two-Phase Outage (Drive Shutdown)

Unlike relays, contactors, and PLCs, ASDs have a variety of setup parameters that can be changed that will influence the ability of the unit to ride-through voltage sags. Such parameters include flying restart, kinetic buffering, and adjustment of the DC bus trip level.

<u>Flying Restart.</u> In applications were the speed control is not super critical, it may be acceptable to enable flying restart features a drive to let the drive catch the motor during spin down and ramp back up to the set speed.

<u>Kinetic Buffering.</u> In applications were the speed is critical, kinetic buffering is possible. ASDs with this feature have the ability to senses a voltage sag or momentary interruption, and enable the motor and load inertia to transfer energy back to the DC bus of the ASD. This allows the inverter to control the rate at which the motor speed drops during the sag. In effect, this “props up” the DC bus of the drive in order to help it ride-through voltage sags.

<u>DC Bus Trip Level Adjustments.</u> The DC bus trip level in which the drive will trip is adjustable on some drives. In many cases, the default level can be set as high as 85 percent of nominal DC bus level. Therefore, two-phase sags of 75 percent on nominal can lead to a shutdown. By setting the trip level down to 50 percent of nominal DC bus level, the drive is able to continue to try and operate. In cases where the drive is heavily loaded, it is possible that over-current trips could occur when the voltage returns to normal. In these cases over-current protection may need to be adjusted.

Figure 4-8 shows the worst case and best case two-phase voltage sag results from EPRI drive testing. Also included on the graph is the data that is expected to represent two-phase measurements at the Modesto and Kingsburg plant. At Modesto, a three-phase I-Grid was used in Building 8 to measured phase-to-phase voltages. The building 6 monitor was plugged into a standard outlet. It is unknown how this circuit was powered, so this data is not included. At the Kingsburg plant, the two installed monitors were placed on the 120Vac secondary of the control cabinet control power transformer. Since the control power transformer primary was connected across phase-to-phase 480Vac, the secondary output of the transformer also represents the percentage of phase-to-phase voltage.

If the ASDs at Del Monte respond in the worst case scenario, then their could be at least five measured events were the ASD would shutdown due to voltage sags. Without testing of the drives in their current configuration and process loading, it is not possible to accurately determine the ride-through performance.

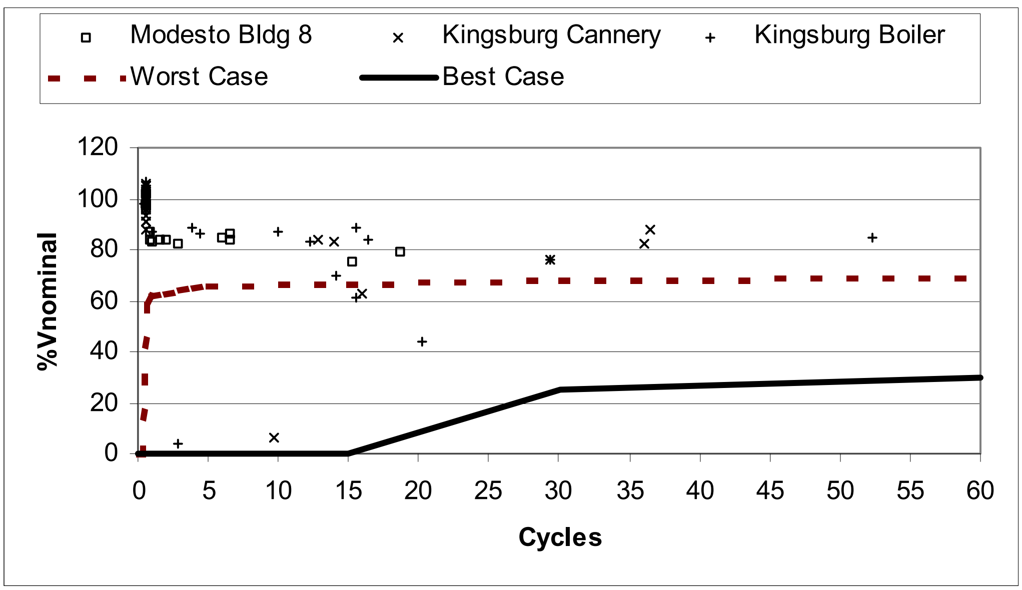


Figure 4-8
Possible ASD Voltage Sag Ride-Through as compared with Phase-to-Phase Power Quality Data from the Modesto and Kingsburg plants.

Note: Sustained outage data not shown on this scale

4.2 Guidelines for Increasing Voltage Sag Tolerance of Control Systems

Based on the results of various EPRI PEAC tests and research projects, some of which were funded by CEC, the following guidelines should be followed to make industrial control systems more immune to voltage sag events.

1. Avoid mismatched control power voltages. If the actual control system nominal voltage is lower than the expected nominal input voltage, the entire control system will be more susceptible to voltage sags. Such mismatches can occur when control power transformers are tapped low or a 230Vac input power supply is connected to a 208Vac source. For relays and contactors, a mismatch of 10 percent of voltage equates to an increase in susceptibility by 10 percent. However, in DC power supplies, the energy stored in the internal capacitors can be as much as 18 percent lower when the input voltage is mismatched by a little as 10 percent--directly equating to a reduction in ride-through time.

2. Provide a stable power source for the control system power supply and I/O control power. Ensuring that the controller Power Supply response to voltage sags will be robust (not easily upset by voltage sags) without considering the I/O control power is only a partial fix. Although the controller power supply may survive voltage sags, the system is still likely to suffer process upsets. Therefore, both the controller power supply and I/O control power must be considered.

3. Consider utilizing DC to power the controller and I/O (Figure 4.9). EPRI tests have confirmed that utilizing a DC power scheme for the PLC or automated controller power supply and I/O control power is an ideal embedded solution for solving voltage sag-related shutdowns. This approach is best designed into the system by the integrator since the controller power supply must be specified as a DC input type, but the I/O modules, sensors, relays, solenoids, and motor starters must be specified for DC control voltages. In systems were the I/O control voltage is already DC, the solution is as easy as replacing the AC input power supply module with the comparable DC input power supply module.

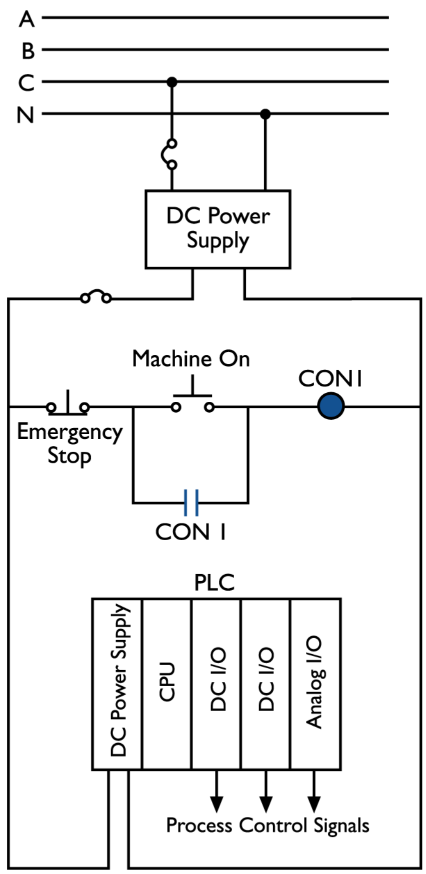


Figure 4-9
DC Power Supply Used to Source PLC as Well as I/O

4. Use Robust DC Power Supply Scheme. It is important to ensure that the 24Vdcpower source remain steady during typical voltage sag events. Figure 4-10 shows different power supply choices, wiring schemes and their relative sensitivity curves. From Figure 4-10 one can deduce that unregulated DC power supplies have the worst ride-through while universal input switch-mode DC power supplies are the most immune over the range of possible voltage sag scenarios.

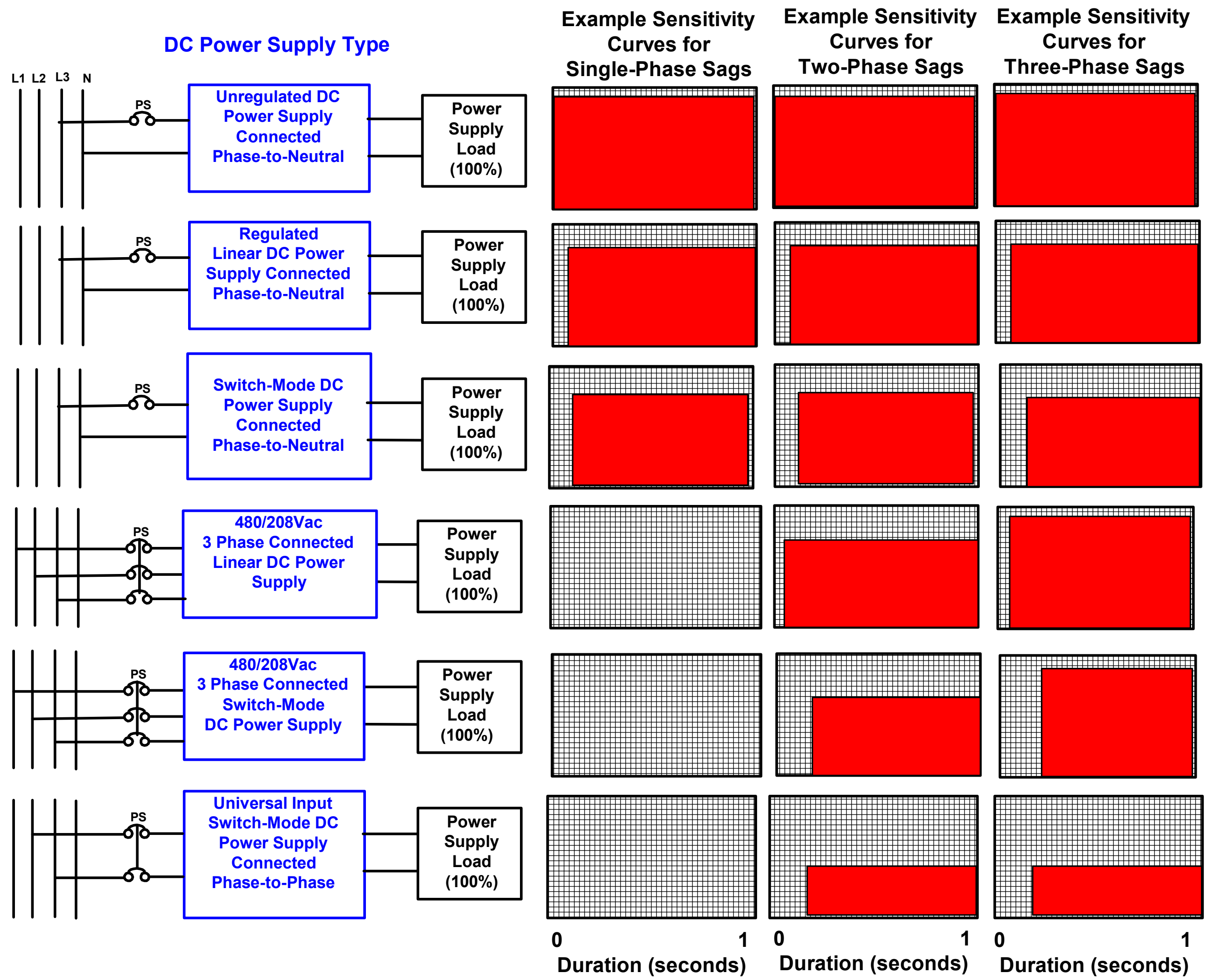


Figure 4-10
Relative Voltage Sag Ride-Through Curves for Various Power Supply Types and Configurations

5. Utilize control relays in the safety circuit (referred to as Master Control Relay (MCR), Machine On, or Emergency Stop circuit) that are hardened against voltage sags When designing with AC components, the importance of selecting control components that are immune to common voltage sags for the safety circuit cannot be understated. When used in the safety circuits or as subsystem power contactors, the selection of the safety circuit relay(s) can make a large difference in the control system's ability to survive voltage sags. Before installing a relay or contactor into the design scheme, the integrator should bench test the units for voltage sag immunity. One way to improve the safety circuit is to avoid general-purpose "ice cube" relays since they are too sensitive to voltage sags. A more robust relay or small contactor should be used instead. Small contactors and IEC style relays are available that meet or exceed the SEMI F47 standard.

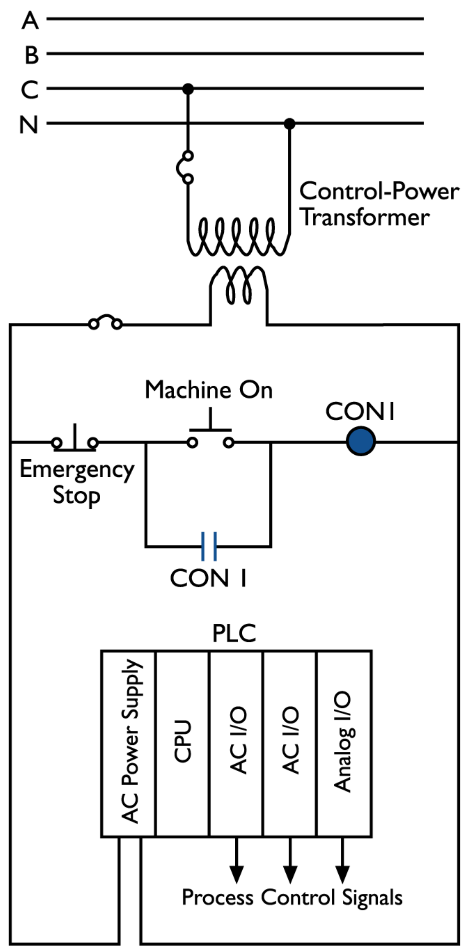


Figure 4-11
The Selection of the MCR or Machine On Relay Contactor (CON1 in Figure) is Critical in AC Powered Safety Circuit Designs

6. Properly maintain controller's battery. Many PLCs utilize lithium-ion batteries to maintain their control programs and non-volatile memory data in the event of a power loss or voltage sag-induced shutdown. Such a loss of the PLC program can cause extended down time due to the need to locate the latest back-up, reload, and restart the process. Since the active process data will be lost in this situation, scrapping of product may be inevitable. In addition to a battery status indicator on the PLC processor, many systems also map this information in the PLC's memory, which can report as an alarm condition on upper-level GUI systems.

7. Utilize a state-machine programming method and/or non-volatile PLC memory. When properly coded, this type of programming technique ensures that the control system will not lose its place in the event of a voltage sag or outage and will result in quicker process restart times.

8. Consider the power source for analog input signals. For analog signals, ensure that the source is stable throughout normal voltage sag events. If two-wire transmitters are used, the DC power supply should be lightly loaded or naturally robust as discussed in guideline 4. If four-wire transmitters are used, consideration should be given to providing power conditioning for the AC voltage source.

9. Only utilize compatible power conditioners. See Appendix A for more information about power conditioners. In general, power conditioners with square-wave outputs should be avoided since the AC input module channels on the PLCs may not be able to resolve the square-wave signal. Only utilize square-wave output power conditioners with the controller manufacturer's assurance that the system power supply and I/O cards are compatible. Furthermore, when using an off-line power conditioner, the transfer time should be within ¼ cycle to ensure that the control system is not upset.

5
DEL MONTE MODESTO EQUIPMENT ANALYSIS AND RECOMMENDATIONS

Note: This section of report contains pricing information based on publically available List Price information available from the vendors at the time of the report's publication. These prices are provided to give the reader an understanding of the general pricing for power quality solutions. In the future, these prices may fluctuate based on market forces.

EPRI PEAC Corporation has analyzed the equipment at the Modesto facility as deemed critical by Del Monte. The Del Monte process at Modesto is summarized in Figure 5-1. The process operations begin by dumping or offloading of the fruit from the delivery trucks. In the next operation, the pit is removed from the fruit. This may be accomplished by the coring operation (pears) with a specific pitting machine as with peaches. Peeling is done either with special blade tools or by caustic solution. The product is then either sliced or diced, depending on what end product it is intended for. Once processed in this way, the product is fed into cans or cups using measurement devices that may work over a linear conveyor or a carousel in which the cups/cans rotate and are filled. After filling, syrup is added for fruits that are not naturally sweet, and the lid for the can is fitted and a seam created to seal it.

Del Monte considers the cook/cool process step as the second most critical operation in the plant. This section is critical because the product already has a significant amount of time and effort invested into it at this point. The cookers take the sealed cans and pull them through a steam bath on a rotating screw conveyor. When this is done, the cans are sent to the next step, cooling, in which they are cooled in a controlled fashion. Both these steps require fairly precise process timing. If too much or too little time is spent in these process steps, the product can be ruined. It follows that voltage sag related shutdown of these processes will lead to downtime and lost product. This is said to be the second most critical process.

After the cook/cool section, the cans are either labeled or put in cartons or they are bright stacked (meaning non labels) for use in the off-season. If the high speed labeling process is interrupted, it will lead to a holdup of the cooking process and stop all progress. Labeling is considered the third most critical process operation.

The most critical process in the plant is the boiler system. This is true because loss of the boiler will shut down everything in the plant. The boiler supplies the steam to the cookers and also for some heating throughout the plant.

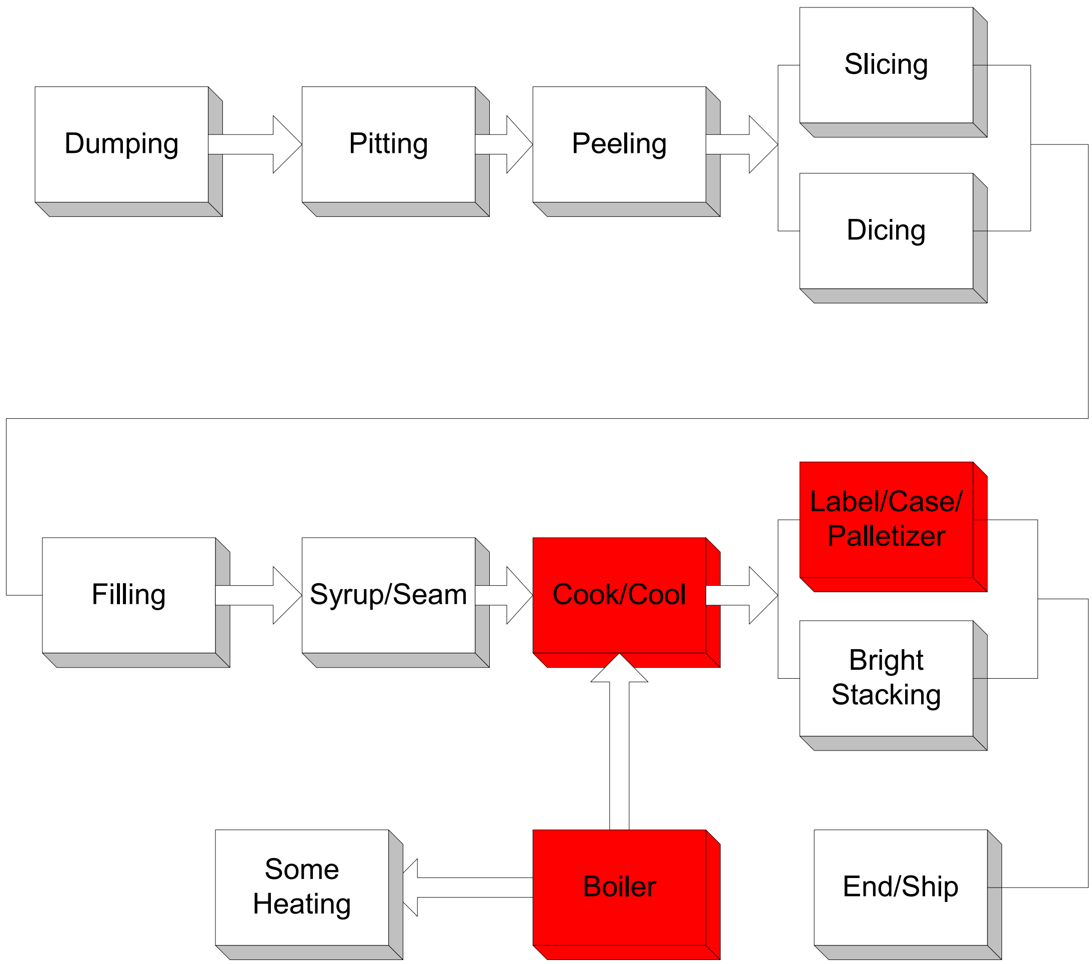


Figure 5-1
Del Monte Modesto Fruit Processing Flow Diagram

Table 5-1 shows the process areas and equipment used in the Modesto plant as well as the report section that addresses each section. See Appendix A for information concerning the recommended power quality mitigation devices.

Table 5-1
Del Monte Modesto Process and Equipment Matrix (Most Critical Equipment Shown in Red)

Report Section	Process Area	# Systems	Controlled by	Remote Racks	Control Power Source
5.1	Dumping	7	Manual via SLC 5/x	0	120 Vac Panel Fed
	Pitting			0	120 Vac Panel Fed
	Peeling	7	SLC 5/03 System	0	120 Vac Panel Fed
	Slicing			0	120 Vac Panel Fed
	Dicing			0	120 Vac Panel Fed
5.2	Syrup Metering	1	SLC 5/05	0	120 Vac Panel Fed
	Syrup Blending Feed	1	PLC 5	0	120 Vac Panel Fed
5.3	Filling	6	SLC 5/04	0	120 Vac Panel Fed
5.4	Syrup/Seam		Stand Alone System	N/A	
5.5	Cook/Cool	1	SLC 5/05 Main Rack	0	120Vac Panel Fed
	Cook/Cool		Remote Racks	20	500VA
5.6	Can Cable	1	SLC 5	1	120 Panel Fed
5.7	Label	10	SLC 5 System/Relays	0	1kVA
5.8	Case	6	SLC 5s	0	500VA
5.9	Palletizer		Stand Alone System	0	
5.10	MCC Rooms	2	SLC 5/x	6	15kVA, 3-Phase
5.11	Boiler	1	Toyo Direct PLC		UPS Fed
	Total	***43***		***27***	

5.1 Front-End Sections: Dumping, Peeling, Slicing, and Dicing

This equipment was examined briefly during the power quality audits, but is not considered to be the most critical area by Del Monte. An appropriate scheme for mitigating voltage sags on these 120Vac Distribution Panel loads is the MinDySC system. The DySC is a good choice here because it can be sized to fit the control power circuit capacity without too much concern about current inrush issues. Furthermore, the unit does not contain batteries, which makes it ideal for using on the plant floor inside of cabinets that are not likely to be opened or checked often. For the purposes of this report, circuits that are direct fed from a 120Vac Distribution panel are estimated to have circuit breaker loads of approximately 13 Amps maximum (1.5kVA at 120Vac). Before implementation of these solutions, Del Monte should verify the actual current loading. Therefore, a 1.5kVA unit employed at each of the seven control power interfaces for will keep the AB SLC-5 PLC and controls from being upset from common disturbances seen at the plant. At $1,144 per unit, the approximate cost for this process area is $8,008.00. See Appendix A for more information on the DySC product.

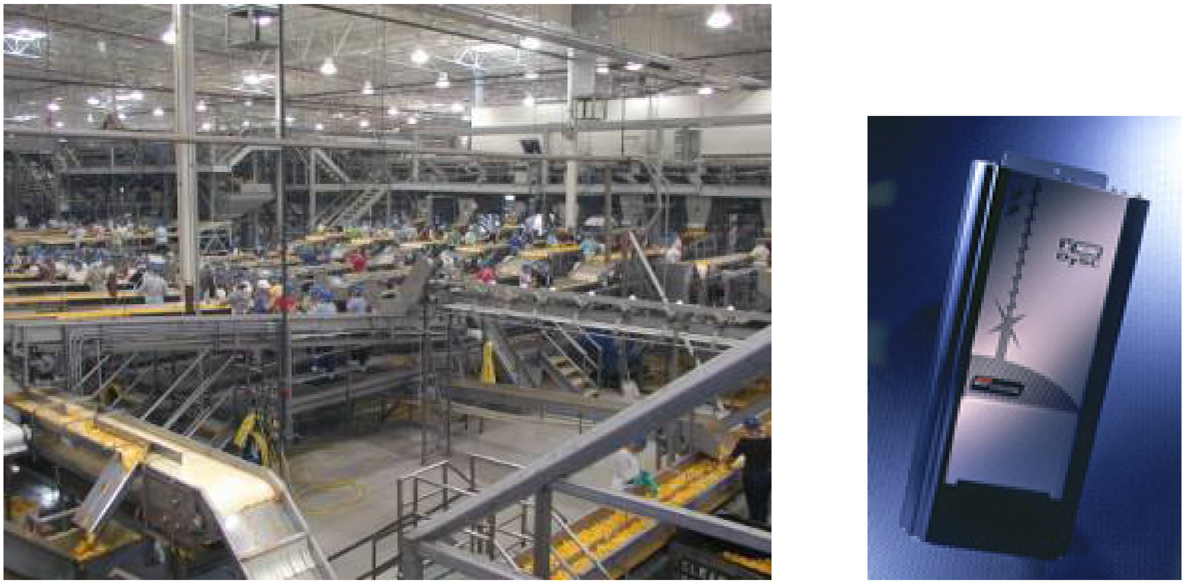


Figure 5-2
Process Front-End Sections Can be Handled with the MiniDySC at Each Control Power Source

5.2 Syrup Metering and Blending

An Allen Bradley SLC-5 PLC controls the Syrup metering process. An Allen Bradley PLC-5 controls the Syrup blending system. As shown in Figures 4-4 and 4-5 of this report, the SLC-5 system is much more robust to voltage sags than the PLC-5. However, since both systems utilize AC I/O it is recommended that each one use a batteryless power conditioner such at the 1.5kVA MiniDySC installed at the 120Vac distribution panel fed control power source for each unit. As recommended in Section 4, both the power to the PLC as well as the I/O power should be conditioned. At $1,144 per unit, the approximate cost to provide mitigation to these process areas is $2,288.00. See Appendix A for more information on the DySC product.

5.3 Filling

The filling system utilizes six different AB SLC-5/4 PLCs with AC I/O. Again, a 1.5kVA MinDySC is a good choice for providing mitigation for this section. At $1,144 per unit, the approximate cost to provide mitigation to these process areas is $6,864.00. See Appendix A for more information on the DySC product.

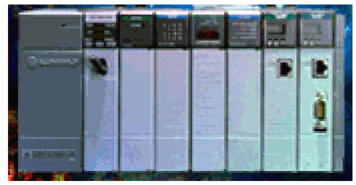


Figure 5-3
Filling Section Processing Fruit Cocktail Product Uses Six SLC-5/4 PLCs

5.4 Syrup/Seam

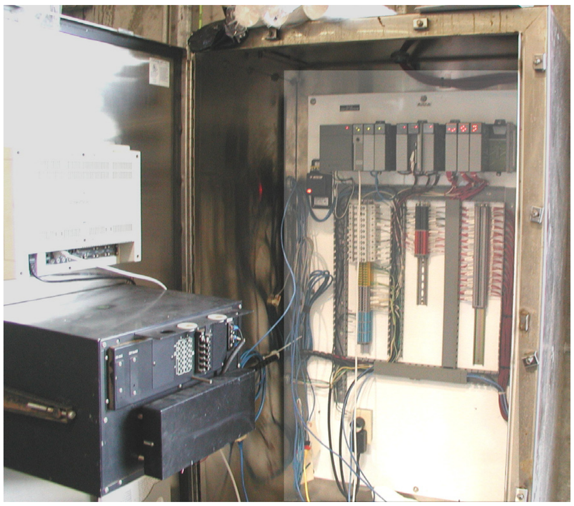
The Syrup/Seam units are stand-alone and are not PLC controlled. During the course of the power quality audit, the units were not considered critical and no information was provided concerning the number of the machines and electrical control requirements. Therefore, solutions for this unit are not included in the report.

Figure 5-4
Syrup/Seam System is a Standalone Unit

5.5 Cook/Cool

The Cook/Cool sections are very critical to the Fruit processing operations at the Del Monte Modesto plant. Cook/Cool system is controlled by a central AB SLC-5/05 PLC. This system has twenty AB Flex I/O racks used for control of the cookers and cooler sections.

Main Rack. The main rack (denoted "PLC-CC Cocktail Cookroom" in control cabinet) utilizes an AC fed power supply. The rack has two scanner modules, three analog output modules, and three AC output modules. There is also a operator interface flat-panel PC and chart recorded installed on the door of the cabinet. There is no UPS power used to support any section of this system. The output modules are connected to AC load end devices such as relays, solenoids, contactors, and motor starters. The main PLC rack and the expected voltage sag ride-through of the rack with a typical AC "ice cube" end device load and typical PC type load is shown in Figure 5-5. The expected voltage sag ride-through of the chart recorder is not known.



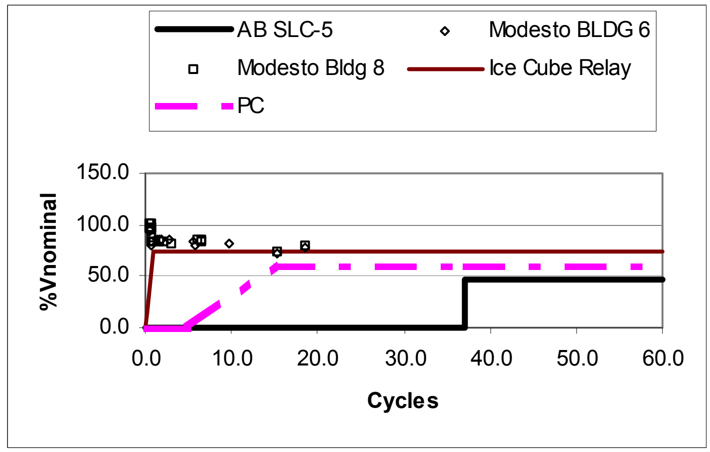


Figure 5-5
Cooker/Cooler SLC-5 Main Rack and Expected Voltage Sag Response

As shown in Figure 5-5, the Allen Bradley SLC-5 PLC itself is very robust to voltage sags and even some momentary interruptions. As shown in the figure, the AB SLC-5's voltage sag ride-through curve indicates that it can withstand an outage last up to 37 cycles. Furthermore, events longer than 37 cycles must be deeper than 47 percent of nominal to shut down the PLC. Looking at the voltage sag data shown on the graph, none of the voltage sags are deep enough and severe enough to affect the SLC-5/03 PLC. Furthermore, the voltage sag ride-through of the scanner modules and analog output modules is expected to be as robust as the PLC itself. However, the susceptibility of the PC and AC end devices, and chart recorder suggest that utilizing a power conditioner here would be appropriate. Also, since this rack governs the operation of twenty different other cooker/cooler control areas, making this area bulletproof to voltage sags is prudent. Estimating that a 20 amp circuit feeds this rack, a 3kVA unit is recommended ($1,774.00)

Remote Racks/Control Cabinets. The remote Flex I/O racks are powered by a local DC power supply, but utilize AC I/O. These racks are in control cabinets that also contain ASDs, master control relays, relays, contactors, and power supplies. Typical devices noted in the newer cabinets are listed below:

- Entrelec DC power supply
- AB 1794-ASB flex I/O that communicates with the Main Rack PLC

- NEMA size one starter by Square D
- Square D type SCO 3 relay
- Saftronics PC7 ASD, approximately 2 hp
- Saftronics GP5 ASD, approximately 5 hp

Two example cooker control cabinets are shown in Figure 5-6.

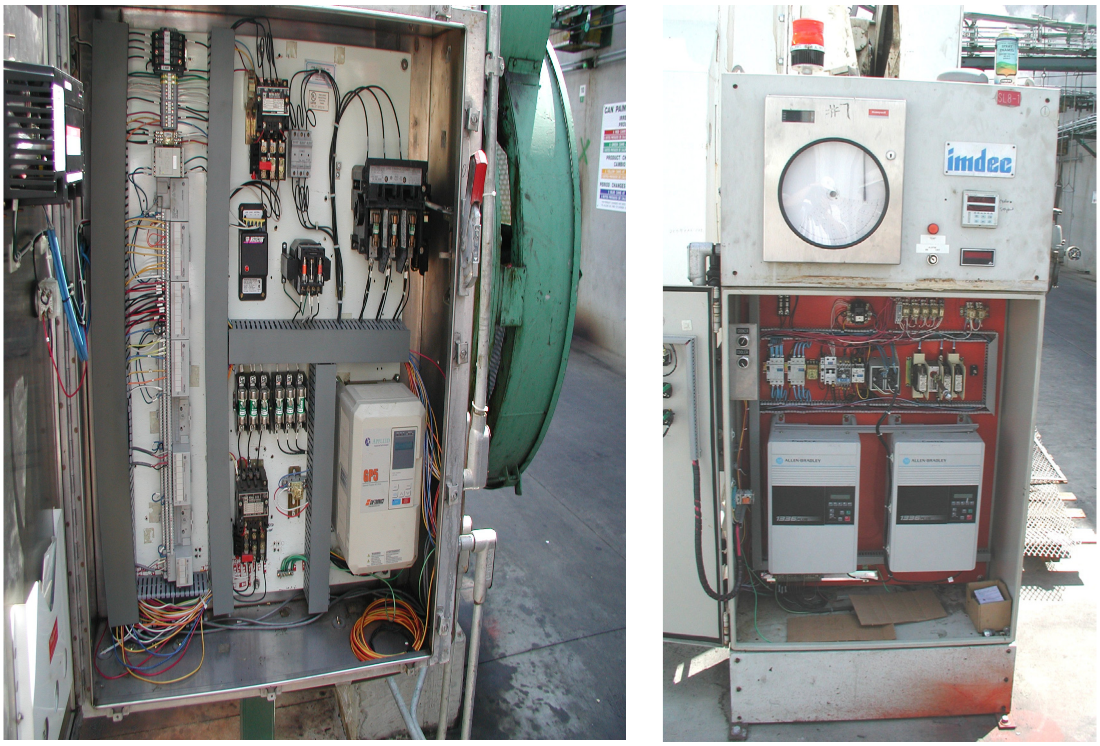


Figure 5-6
Two Different Cooker Control Cabinets (Newer on Left, Older on Right)

A one-line diagram of an example cooker control cabinet is shown in Figure 5-7.

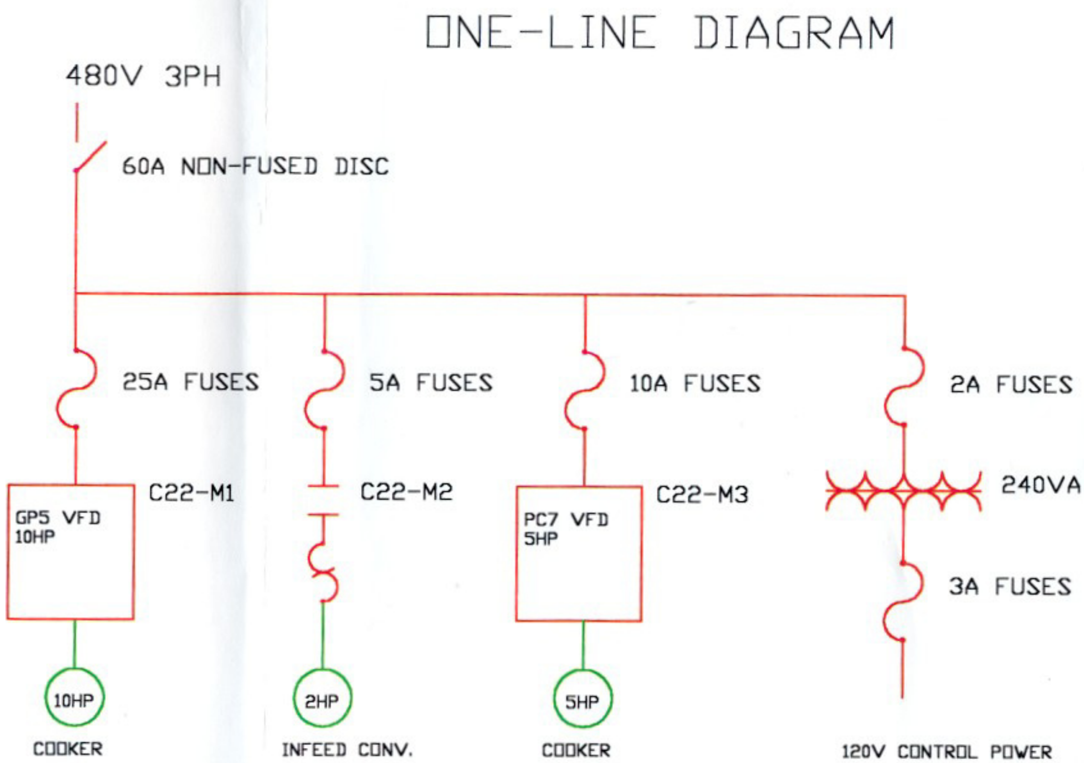


Figure 5-7
One-Line Diagram of Cooker Control Cabinet

The control power for each rack is typically fed by a 240VA to 500VA control power transformer. The recommendations for these racks are to utilize a 120Vac, 500VA MiniDySC ($750.00) installed at the secondary side of the control power transformer. For twenty total cabinets, the cost for hardening this section is $15,000. In addition, each drive should be set up to take advantage of flying restart, kinetic buffering or DC Bus voltage trip level adjustments that may be available for the given drive. Del Monte utilizes a mixture of drives including the Allen Bradley and Saftronics. The Saftronics drives have a restart option that is disabled in the initial configuration. Also, the holding DC voltage can be adjusted.

5.6 Can Cable System

The Can Cable Controls are shown in Figure 5-8. This system conveys the cans from the cooker and cooler section to the labeling section. A SLC-5 PLC is used to control the system (left picture). A separate control cabinet with motor starters is also utilized (right picture). It is recommended that two 1.5kVA MiniDySC systems be used to provide conditioned power to the control sections in both cabinets ($1,144 ea). EPRI PEAC does not have drawings for this system. Therefore, smaller DySC units may be applicable based on the actual control power requirements. The estimated cost for the proposed solution is $2,288.

Figure 5-8
Can Cable System Controls

5.7 Labeling

The high-speed labeling systems were identified by Del Monte as critical to process flow. The labeling systems use two different control schemes. One type utilizes an AB SLC-5 series PLC for automation controls. The other labelers use relay logic only to accomplish control. A typical Krone Canomatic system is shown in Figure 5-9. According to the audit information, there are 10 labelers used at Modesto.

Figure 5-9
Krone Canomatic Labeler at Del Monte

The power quality analysis of one of the PLC based label machines is shown in Figure 5-10. The susceptibility of each section of the left and right cabinets is noted. The cabinet controls are fed by a 480/120Vac, 1kVA control power transformer. In order to make this system robust to voltage sags, a single 1.5kVA MiniDySC should be used, connected to the secondary of the 1kVA transformer. The cost per cabinet and area is estimated at $1,144 or $11,144 for the entire labeling area.

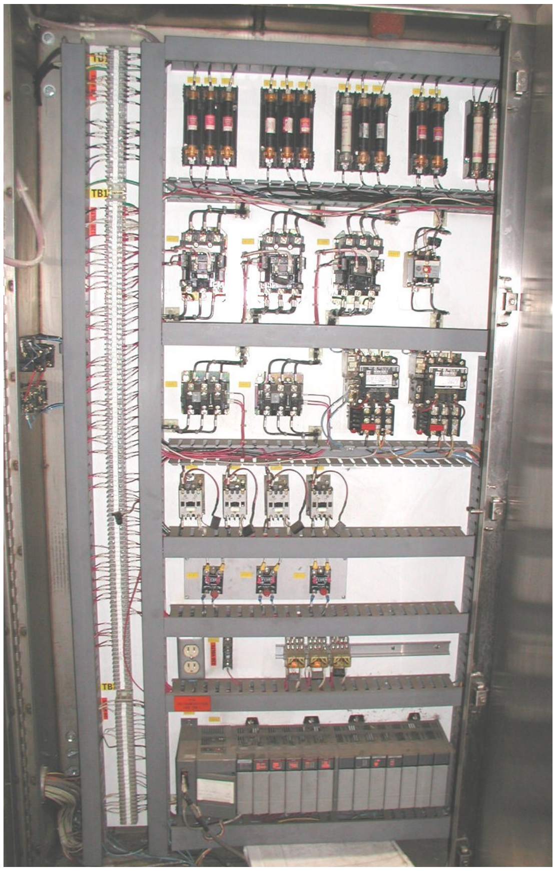
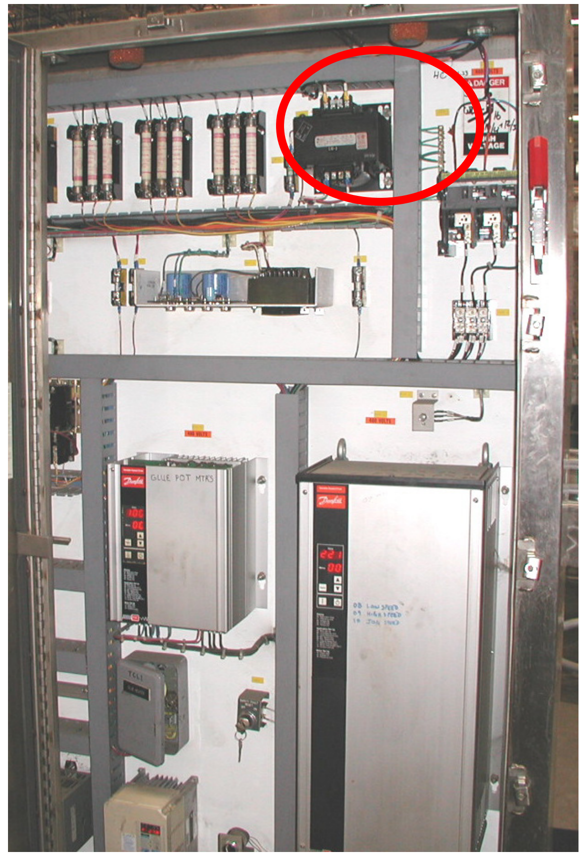
	
Cabinet Left Side *Susceptible Components:* *AB SLC-5 (Low)* *AC "Ice Cube" Relays (High)* *AC I/O devices (High)* *Motor Starters (Moderate)* *Contactors (Moderate)*	**Cabinet Right Side** *Susceptible Components:* *ASDs (Moderate)* *Linear Power Supply (Moderate)*

Figure 5-10
Krone Labeler Cabinets With 1kVA Control Power Transformer Identified

5.8 Case

There are six SLC-5 based casing systems, each of which utilize a 500VA control power transformer. If these units utilize DC controls, then no power conditioning is recommended. However, if AC controls are used, it is recommended that six 120Vac, 500VA MiniDySC units be used for this area with a total cost estimated at $4,500.

5.9 Palletizers

The palletizers are stand-alone and are not PLC controlled. During the course of the power quality audit, the units were not considered critical and no information was provided concerning the number of the machines and electrical control requirements. Therefore, solutions for this unit are not included in the report.

5.10 MCC Rooms (2)

Two separate MCC rooms were audited, both of which are nearly identical in their control layout. The first MCC room is located near the process front-end section. The second MCC room is located near the filling area.

Figure 5-11
MCC Room where PLC-SV System is installed

A unique feature of these two areas is that the control power for the motor controls and PLC racks are derived from a three-phase 15kVA 480/208Y120 transformer as shown in Figure 5-12. The output of the transformer feeds a distribution panel for the 120Vac loads.

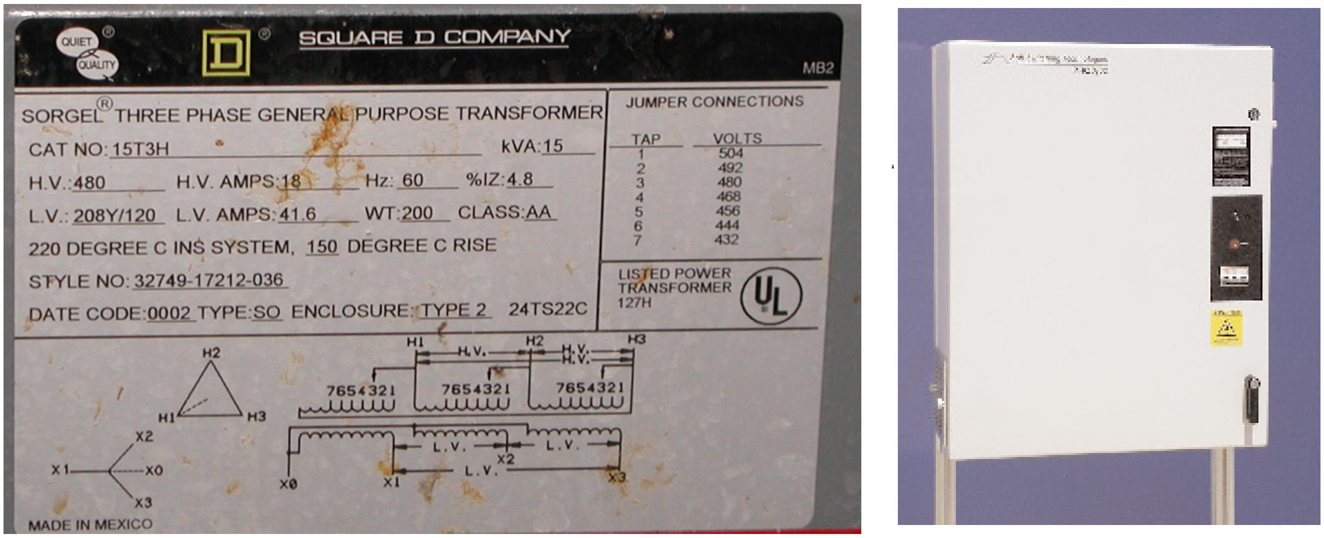


Figure 5-12
Transformer Nameplate and Potential ProDySC Solution

A possible solution to protect all loads in this area is to use a 3-phase 21kVA Pro-DySC installed on the 480Vac primary side of the transformer ($11,000 ea). The total cost of protecting both MCC sections is estimated at $22,000. Given that Del Monte did not deem the MCC areas as critical, it may be difficult to justify the $22,000 investment here. Del Monte should study the distribution panel schedule for the process loads fed by the 15kVA transformer to determine if more payback potential can be realized.

5.11 Boiler

Given the critical nature of process steam, Del Monte has designed robustness into the boiler controls at the Modesto plant. A properly maintained BEST UPS is used to power the control sections of this system. It is recommended that if the plant experiences any voltage sag related shutdowns in the Modesto Boiler System, the voltage sag ride-through parameters of the exhaust blower ASD should be examined to see if they need to be adjusted. Based on reports from Del Monte concerning the Kingsburg boiler, it is vulnerable to voltage sags. This is due to the fact that the boiler does not have a UPS or power conditioning on the controls. Therefore, voltage sags and momentary outages can result in a “flame out” condition that will require a restart of the flame safety sequence to bring the boiler back on-line. Further investigation of the boiler control scheme at Kingsburg is suggested as part of the future work discussed in Section 6.1 of this report.

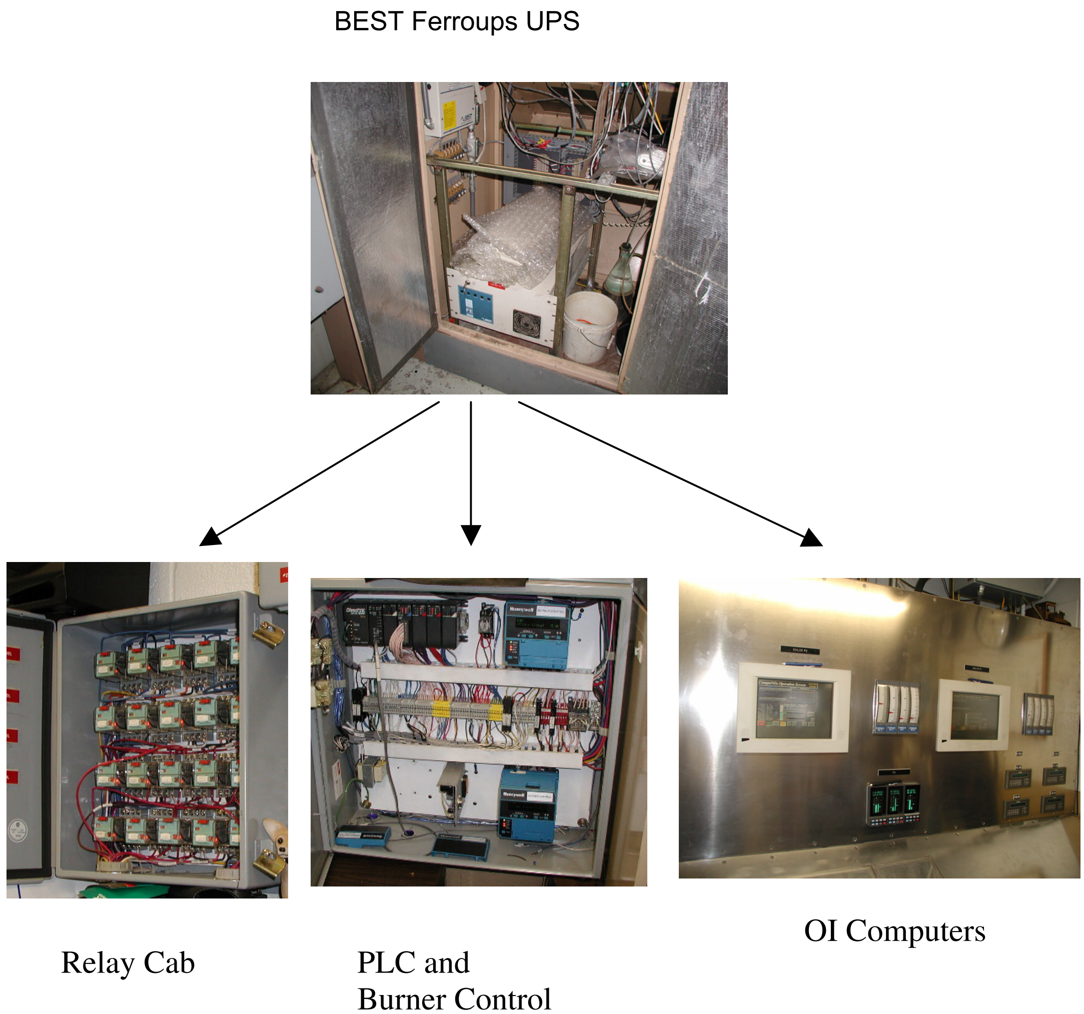


Figure 5-13
Boiler System UPS Power Scheme

5.12 Summary of Costs and Recommendations for the Modesto Plant

Based on the analysis provided within this section, a summary of the recommendations and costs given in Table 5-2. The Dynamic Sag Corrector, or DySC technology is shown as the recommended solution in this analysis. The DySC is easier to "size" for a given application where limited information is known about the loading and inrush current requirements at each load location. Other solutions shown in Appendix A (such as the Dip Proofing Inverter, Constant Voltage Transformer, or Coil Hold-in Device) may also be applied if more loading information is known. If voltage sag testing and field measurements were made on each of the areas, the exact sizing for the voltage sag mitigation equipment could be determined as well as the lowest cost solution.

Table 5-2
Modesto Process and Equipment Recommendation Summary

Report Section	Process Area	Deemed Critical?	Recommendation	Cost/Unit	Units	Cost/Area	Note
5.1	Dumping Pitting Peeling Slicing Dicing	No	1.5kVA MiniDySC	$1,144	7	$8,008	
5.2	Syrup Metering Syrup Blending Feed	No	1.5kVA MiniDySC	$1,144	2	$2,288	
5.3	Filling	No	1.5kVA MiniDySC	$1,144	6	$6,864	
5.4	Syrup/Seam	No	None	0	0	$0	1
5.5	**Cook/Cool**						
	Main Cabinet	**Yes**	**3kVA MiniDySC**	**$1,774**	**1**	**$1,774**	
	Remote Cabinets	**Yes**	**500VA MiniDySC**	**$750**	**20**	**$15,000**	
5.6	Can Cable	No	1.5kVA MiniDySC	$1,144	2	$2,288	2
5.7	Label	Yes	1.5kVA MiniDySC	$1,144	10	$11,440	
5.8	Case	Yes	500VA MiniDySC	$750	6	$4,500	
5.9	Palletizer	No	None	0	0	$0	
5.10	MCC Rooms	No	21kVA 3-Phase ProDySC	11,000	2	$22,000	
5.11	**Boiler**	**Yes**	**Check ASD Setup**	**0**	**0**	**$0**	**3**
				Total Cost		$74,162	4
				Critical Areas Only		**$28,214**	

Notes:

1.0 No Information provided on this system during audit. No recommendations made.

2.0 EPRI PEAC recommends considering this equipment as critical since a back-up in the can cable line could cause a shutdown of the cook/cool system.

3.0 The Boiler controls are on a BEST UPS, which is on a regular maintenance schedule. The only recommendations here are to check the ASD setup for maximum voltage sag ride-through configuration.

4.0 This section of report contains pricing information based on publically available List Price information available from the vendors at the time of the report's publication. These prices are provided to give the reader an understanding of the general pricing for power quality solutions. In the future, these prices may fluctuate based on market forces.

6

FUTURE WORK/ROAD MAP

6.1 Future Work With Del Monte

In this initial project, CEC and EPRI began the work of understanding the food processing industry and the impact of power quality on these processes. Likewise, Del Monte has become more informed about the affect of power quality on process systems and solutions to make these systems more robust. In order to continue on a path of improving the response of Del Monte's process systems to power quality disturbances, the following future work is suggested in order of importance.

1. Power Quality Audit and Testing at Kingsburg Plant. Del Monte has voiced concerns over boiler and process system shutdowns for the Kingsburg plant. Given the product quality problems associated with the shutdown of a tomato processing plant, the problems at this plant should be tackled first. The data obtained during the limited monitoring period seems to indicate that the power quality at Kingsburg is not as good at the Modesto facility (See Table 3-9, Figure 3-9). EPRI PEAC proposes that a two to three day power quality audit with on-site voltage sag testing be conducted as soon as feasible. Potential solutions would be brought with the power quality audit team so that the effectiveness could be proven on-sight. Now is an opportune time to accomplish this since the production season has ended. Since the effort at Kingsburg would be a field audit instead of the research and technology transfer type effort that was conducted initially at Modesto, the auditing, testing, and reporting would be accomplished completely within 3 to 4 weeks.

2. Testing and Implementation of the Proposed Solutions at Modesto. Given the recommendations from this report, it would be feasible to test the recommended solutions on the most critical systems. Again, these are the cook/cool, labeling, and casing areas. EPRI PEAC could work with the mitigation equipment supplier to have representative equipment on-hand for the testing. Once the solution is proven, Del Monte could move forward to purchase required hardware. Testing may also reveal if power conditioning is necessary for some systems such as the Cook/Cook main cabinet. Considering the fact that only limited production takes place in the off season time, it is important to move ahead with this effort so that completed solutions can be installed before the beginning of next year's production season.

3. Power Quality Effort at the Hanford Plant. In order to cover all three of the major fruit and tomato processing facilities for Del Monte, the Hanford plant should be considered for a power quality effort. Proposed tasks for this facility include the installation of I-Grid power quality monitor(s) and power quality auditing and testing at the facility. The estimated start-to-finish time for this work is 4 to 5 weeks.

6.2 Road Map for Overall PQ in Food Processing Effort

6.2.1 Stakeholder Participation to Develop Standards

For overall power quality effort in food processing to be successful, all stakeholders must be involved to work toward feasible solutions. Ideally, the goal is to achieve harmony between the utility electrical system and the end use electrical systems. This concept is known as System Compatibility. As shown in Figure 6-1, true System Compatibility can only be achieved when the process equipment suppliers, electric utilities, and food processing manufacturers work together. Without the participation of just one of the "legs" of this three-legged stool, it cannot not stand.

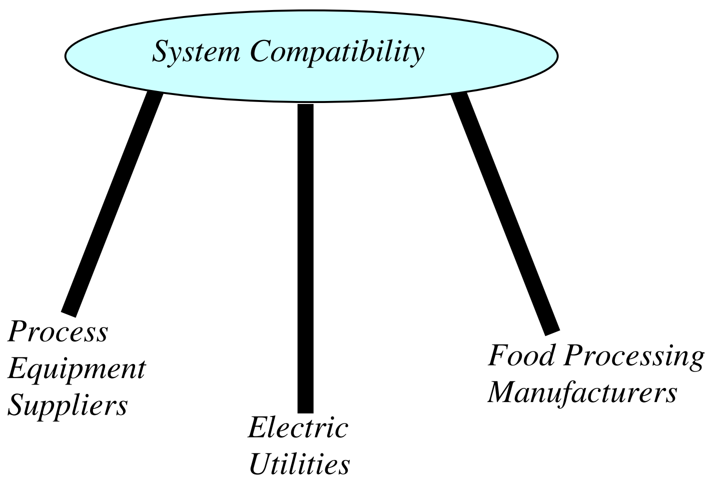


Figure 6-1
System Compatibility For The Food Processing Industry

Furthermore, these three major stakeholders must work together to develop a common target in which they will build their electrical systems. This common objective for this group should be an industry specific power quality standard. As in SEMI F47 (see Figure 3-7), this power quality standard would set an immunity goal for the facility and process equipment. Furthermore, it would provide a benchmark for the utility to provide voltage quality that is above the defined immunity goal. Once a standard has been determined, all three of the stakeholders can take aim at the same goal. Therefore, as the process equipment suppliers, electric utilities, and food processing manufacturers begin their initial work with one another to better understand the electrical environment and process system requirements, their end goal must be the development of a power quality standard.

An industry type standard has been successfully implemented in the Semiconductor industry. Working through their own trade organization known as the Semiconductor Equipment and Materials International (SEMI), this specific industry type standard is leading to factory systems that can withstand common voltage sags without costly shutdowns. Implemented in 1999, the SEMI F47 standard is shown below.

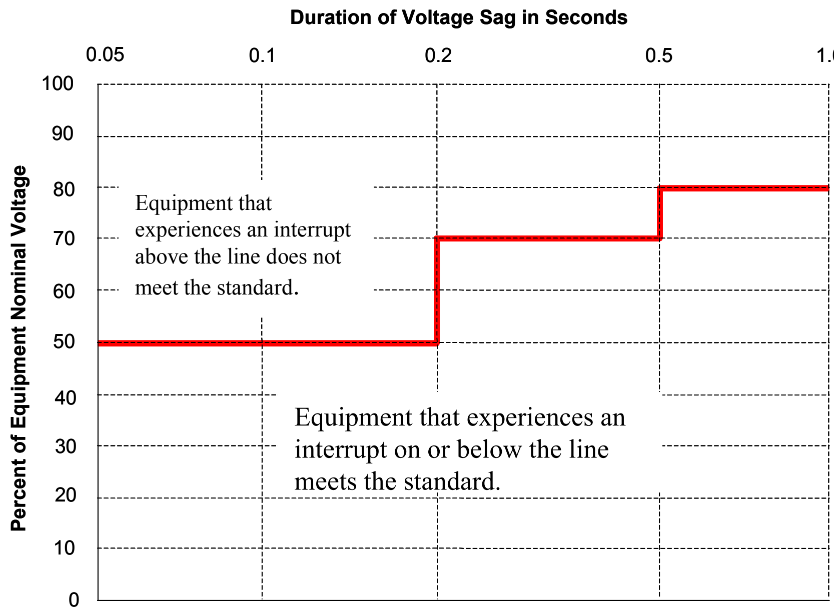


Figure 6-2
The SEMI F47 Standard Serves As Proof That Industry Standards Are Feasible

If a standard is to be developed for the food processing industry, then it must be implemented from within.

6.2.2 Head Start for Food Processing Power Quality and Standards Efforts

The California food processing industry has a head start in the development of a power quality standard for their industry. Unlike at the start of the Semiconductor effort, a significant knowledgebase exists now for other industry type initiatives. Techniques for building better processes systems through embedded solutions and robust design schemes are known. Many different electrical subcomponent tests have been done that qualify equipment to the SEMI F47 standard. Furthermore, example-testing methodologies are available as well to use as guidelines. These existing resources give the food processing power quality initiative an unprecedented head start in developing their own power quality standard. A future "Food Processing" standard could chose the SEMI F47 curve, ITIC, or other set another goal. If the industry decided to adopt an existing standard as the guide would allow for an immediate base of compliant devices.

6.2.3 Proposed Road Map Steps to Develop a Food Processing Industry Standard

Given the ability to have robust components and design schemes currently available for designers to incorporate into process systems, the food processing industry should move ahead with a plan to make a similar standard. This section details an envisioned roadmap that could lead to such a standard for the food processing industry.

The roadmap presented herein is based on a collaborative effort from the stakeholders which would include the California Energy Commission, other utilities who have food processing as a major industry, food processing manufacturers as well, research firms, and consultants. By combining resources, the end goal of creating a workable and accepted industry standard can be realized. The envisioned tasks are outlined below.

Task 1: Implement Web Based Platform to Manage and Promote this Standards Effort. This web site will be used to present the initiative's charter and goals, initiative updates and relevant research results, standards meeting minutes, draft standards, and upcoming events. Basically, this web site will be an up-to-date technology transfer tool for all stakeholders.

Task 2: Assessment of Impact of PQ Disturbances on Process Automation Equipment for Food Processing Industries. The goal of this task is to complete a baseline assessment for food processing industries to evaluate the process control tool and equipment requirement and its interaction with the electrical environment. These assessments will be undertaken in cooperation with candidate food processing industries in California and well as other regions in which a stakeholder steps forth to sponsor other work

Successful completion of this task will provide a baseline of food processing industry so that the utility environment, process and equipment requirements are known. Furthermore, the approach will be to demonstrate solutions during this phase in order to build a case for the feasibility of a power quality standard.

Task 3: Develop Target Ranges for Process Equipment Immunity Based on Controlled Testing. The goal of this subtask is to evaluate the component level sensitivity for food processing industry. Where existing data for components sensitivity is not available, controlled lab testing will be conducted to identify the component level sensitivity.

Successful completion of this task will be measured by the development of a target immunity range documentation for process control equipment for the food processing industry.

Task 4: Provide Technical Support to the Food Processing Industry PQ Standards Coordinating Committee. The goal of this task is to provide technical support to the food processing PQ Standards Coordinating Committee that will be formed as part of this PQ initiative. This standards group will need to include stakeholders from the manufacturing industry, process equipment suppliers, electric utilities, consultants, and researchers. The group must be formed either under the umbrella of a recognized food processing organization or with recognition of major industry organizations.

Such target organizations could include:

- Grocery Manufacturers of America
- California League of Food Processors
- North American Association of Food Equipment Manufacturers (NAFEM)
- Food Processing Machinery and Supplies Association
- The Institute of Food Technologist

Successful completion of this task will be measured by the development of a voltage tolerance standard for the food processing industry.

Task 5: Develop PQ Recommended Practice Document for Electrical Design and Equipment Selection for the Food Processing Industry. The goal of this task is to develop a recommended practice document for electrical design and equipment selection for the food processing industry. The recommended practice document will provide guidance to plant personnel on properly integrating process equipment to minimize power quality issues for existing plants and for new plants.

Successful completion of this work will be measured by the development of a practical hands-on guidebook for recommend practice for electrical design and equipment selection for the food processing industry.

Task 6: Technology Transfer Activities. This task will begin from the start of this effort with information posted on the initiative web site. Activities to engage the industry such as participating in industry conferences, tradeshows, and writing technical papers are envisioned to be included in this work. The CEC and selected consultants should seek specific tech transfer opportunities in 2003 such as: California League of Food Processors Expo and Showcase in Sacramento on February 4th -5th, 2003. CEC is currently slated to present "Food Industry Electric Power Quality" on February 5th. See http://www.clfp.com

1. North American Association of Food Equipment Manufacturers Trade Show, September 5-7, 2003, in New Orleans. See http://www.nafem.org/.

2. Food Processing Machinery and Supplies Association Show. October 13th-15th, 2003 in Las Vegas. See http://www.processfood.com.

3. IFT Annual Meetings and Food Expo, July 26-30th, 2003 in Chicago. See http://www.ift.org

The technology transfer task will continue until the project is completed with the final reporting. The goal of this task is to transfer the knowledge gained from the overall effort to decision makers in industry and government. Successful completion of this task will be measured by the ongoing transfer of knowledge to industry through the initiative web site, engaging industry through conferences, and providing a comprehensive final report.

The proposed schedule for the roadmap tasks is shown in Figure 6-3.

	Task Name	Duration	Start	Finish
1	Project Start	0 days	Wed 1/1/03	Wed 1/1/03
2	Task 1: Implement and Maintain Standards Web Site	522 days	Wed 1/1/03	Thu 12/30/04
3	Task 2: Assessment of PQ Impact on Process Equipment	9 mons	Mon 2/3/03	Fri 10/10/03
4	Task 3: Develop Target Ranges	3 mons	Mon 6/2/03	Fri 8/22/03
5	Task 4: Support for PQ Standards Effort	414 days	Mon 6/2/03	Thu 12/30/04
6	Task 5: Develop Recommended Practices Document	88 days	Mon 9/1/03	Wed 12/31/03
7	Task 6: Technology Transfer	523 days	Wed 1/1/03	Fri 12/31/04
8	Project Completion	0 days	Fri 12/31/04	Fri 12/31/04

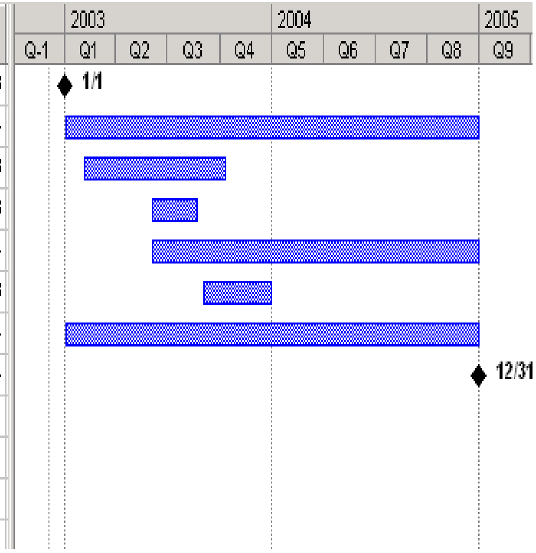


Figure 6-3
Proposed Roadmap Schedule for Food Industry Power Quality Standards Effort

A

SELECTED SINGLE-PHASE POWER CONDITIONING DEVICE DESCRIPTIONS AND SIZING

Note: This section of report contains pricing information based on publically available List Price information available from the vendors at the time of the report's publication. These prices are provided to give the reader an understanding of the general pricing for power quality solutions. In the future, these prices may fluctuate based on market forces.

Control Voltage Level Solutions

Often the voltage dip ride-through capability of an equipment or machine is directly related to the ability of one or more small "weak-link" components to survive the voltage dip event. Effective strategies for improving tool's voltage sag immunity are:

- Use "Selective Power Conditioners" on susceptible loads
- Embed the Solution through design and component selection strategies
- Utilize a combination of both strategies

In many cases, small power conditioners can be applied to control circuits to make equipment more robust to voltage sags. Figure A-1 shows typical devices of this nature.

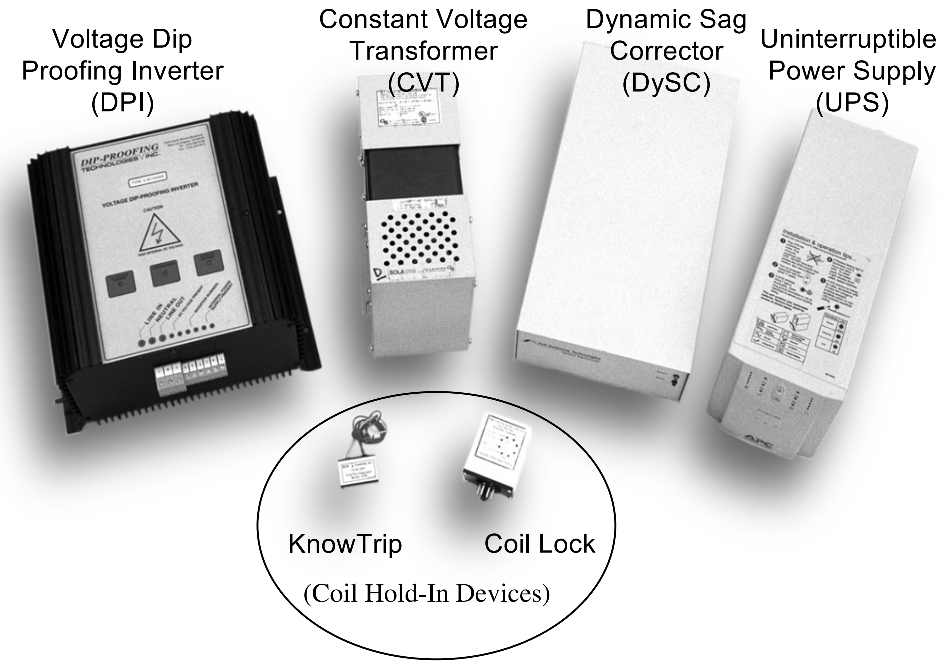


Figure A-1
Typical Single-Phase Power Conditioning Devices

The Constant Voltage Transformer (CVT)

The CVT (a.k.a. ferroresonant transformer) is best defined in the SOLA literature as follows: "The ferroresonant transformer is a device that maintains two separate magnetic paths with limited coupling between them. The output contains a parallel resonant tank circuit and draws power from the primary to replace power delivered to the load. The transformer is designed so that the output path is in saturation while the other is not. As a result, a further change in the primary voltage will not translate into changes in the saturated secondary voltage, and voltage regulation results."

CVTs offer protection from voltage sags as well as voltage swells. Units can be ordered from suppliers such as SOLA and ACME that have multiple taps. For this reason, the existing step-down control power transformer can be replaced with a CVT. These devices will allow for much better voltage sag ride-through if they are sized to at least twice the nominal VA requirement. Oversized in this manner, CVTs can supply a 100% output when the input voltage has dropped to as low as 45% of nominal. Figure A-2 displays the typical CVT performance characteristics various loads.

As indicated by Figure A-2, the CVT will not power the load circuit in the event of a momentary outage or a very severe voltage sag. The tricky part of applying the CVT is dealing with high inrush currents. As a general rule, the CVT should be sized to handle the RMS value of the in-rush current of the load. This rule of thumb may lead to oversizing the unit for some applications that have low nominal current, such as systems with large three-phase contactors. If the CVT is undersized for the systems in-rush load, the output will collapse momentarily or possibly indefinitely.

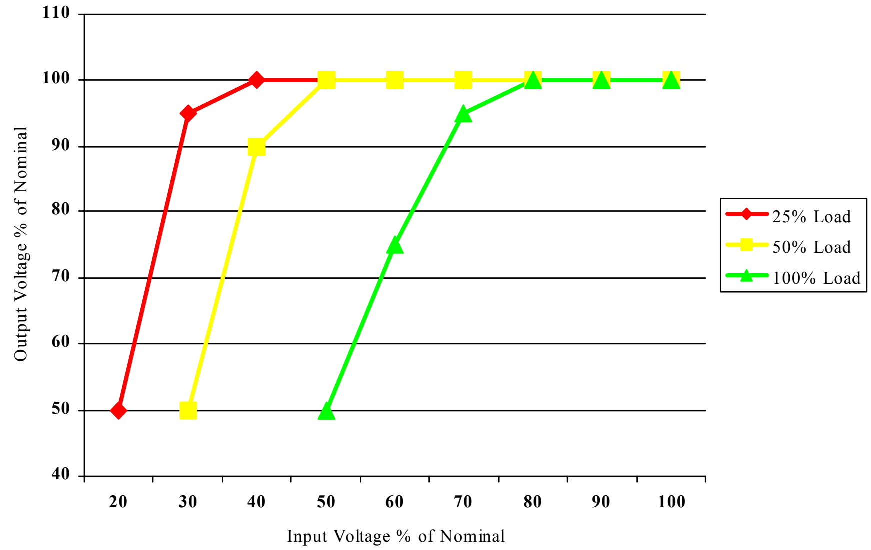


Figure A-2
Typical CVT Performance as a Function of Load

Web Sites: *www.bestpower.com* , *www.sola-hevi-duty.com*

The Uninterruptible Power Supply (UPS)

The UPS can come in two basic types: off-line and on-line. An off-line or standby UPS normally passes the power straight through from the input of the unit to the output. When a voltage sag or outage is detected, the unit switches to a battery and provides an inverter output to the load. If the transfer is fast enough (< 1 cycle) and is in phase with the incoming voltage, typical control components are not likely to be affected by the sag event. Since it is only switched into the circuit when a voltage sag or outage occurs, an off-line UPS can be sized to the nominal current required by the load. One drawback of the off-line UPS is that it does not mitigate voltage swells or noise from the incoming power.

The on-line UPS continually passes conditioned power from the input of the unit to the output. For this reason, the unit must be sized to handle the in-rush current for the load and will generally be more expensive for the required load. The best design for this type of unit has a ferroresonant transformer on the front end of the unit to mitigate voltage swells and noise.

Ultimately, the determination of whether to use a UPS or some other voltage conditioning device depends on whether the load required power during a brief outage. If this is the case, the UPS is the better choice. The performance of individual UPS models varies.

Web Sites: *www.bestpower.com*, *www.apcc.com*, *www.exide.com*, *www.leibert.com*

The Dip Proofing Inverter (DPI)

The DPI falls into a class of device referred to as batteryless UPS systems. Since the DPI operates only when the voltage sag is detected (off-line technology) it only needs to be sized for the nominal load. The device basically continually rectifies incoming AC voltage to charge the DC bus capacitors. When a voltage sag is detected that drops below an adjustable threshold, the line to the incoming power to the device is opened and the DPI supplies a square-wave output to the load for about 1 to 3 seconds. The amount of time that the load will be supplied can be calculated based on the real power and the energy storage of the particular DPI. The amount of time that the device can supply power to the load can be calculated by the following formula:

t= [usable stored energy (joules)] / [load power required in watts]

For a 500 VA unit, the usable stored energy is 80j when powered at rated voltage. If the actual load were 60W, the unit can supply voltage to the load for an outage or sag lasting up to 1.33 seconds.

It is important to note that if the DPI is operated at 208Vac, as with some semiconductor tool applications, the available power must be de-rated. This is due to the fact that the unit's capacitors are designed to operate at 230Vac. When the actual operating voltage is 208Vac, the storage energy in the device is 18% lower resulting in decreased ride-through time. If the decrease is not acceptable, the next largest size unit should be used or the unit should be specified with additional capacitors on the purchase order.

Because the DPI does not have batteries, required maintenance is less than a battery UPS. The rated lifetime for the capacitors is twelve years. The DPI is also compact and light weight when compared to either the CVT or the UPS. Since the standard voltage setups for the units are 120 and 230Vac, the purchaser must specify if the nominal voltage is different in order for the factory to preset the DPI (e.g. 208Vac). The DPI output is a square wave, which has been found to be incompatible with only a handful of components.

The DPI voltage sag threshold level can be adjusted to determine when the load will transfer to the capacitor bank. The unit can also be set to specifying the amount of time that the inverter should run. If the unit is installed with the factory settings, it may allow some of the more sensitive components, such as general purpose relays and PLCs, to shutdown before it makes the transition. When set to switch to capacitor power at the highest setting (90% of nominal voltage), the unit performs well to prop up sensitive loads. The square wave output has been found to be incompatible with only a handful of components such as some AC input channels on PLC I/O cards.

***Web Site**: www.measurlogic.com*

The Dynamic Sag Corrector (DySC)

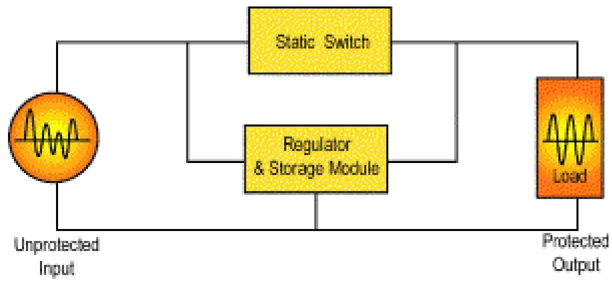


Figure A-3
Principle Of Operation Of The DySC

The miniDySC is a transformer-less series injection type of dynamic sag correction device, a block schematic for which is shown in Figure A-3. The proDySC is a three-phase version of the miniDySC, and incorporates a small-rating transformer. The miniDySC and proDySC can boost the incoming ac line voltage by more than 100%, and can provide momentary ride-through protection for sags down to zero volts. The duration of ride-through protection is dependent on the stored energy. However, the voltage boost function is not limited by any stored energy in the system. Rather, the system is optimized to handle short-term voltage sags of up to 2 seconds, and can be cycled as frequently as twice every minute. The DySC however, is not designed for extended brownouts.

The DySC normally operates in a bypass mode until the onboard microprocessor detects a voltage sag condition. Transfer to the 'sag correct' mode is made in less than half a cycle, and the DySC continues to deliver a regulated sinusoidal output waveform to the load. The DySC transfers back to bypass mode upon detecting a 'normal' utility line voltage. Under normal, (i.e. bypass) conditions, DySCs are over 99% efficient and cause no additional line current distortion. There are no batteries to be replaced or maintained, resulting in a long operating life.

Web Site: www.softswitch.com

The Coil Hold-In Devices

The knowtrip and the Coil Lock are designed to hold in individual relays and contactors. Units are available at 120, 230 and 480Vac. The device is designed to hold the coil in down to 10 to 20% of nominal voltage. These features make it ideal for motor control center applications. The size of the device depends on the resistance of the coil in the relay.

Web Sites: www.scrcontrols.com, www.pqsi.com

Bonitron 3460 Ride-Through Module

Bonitron's M3460 Ride-Thru provides protection from AC line voltage sags for AC drive systems that use a fixed DC bus, such as AC PWM adjustable speed drives (ASD). ASDs are commonly used in industry to improve control over processes where very accurate motor speed control is required. Unfortunately, ASDs are quite susceptible to problems when fluctuations in incoming power occur. Bonitron's Ride-Thru provides protection from line voltage sags or the momentary loss of one phase. This provides the security of "riding through" these events without motor speed control loss, drive shutdown, or the problems associated with other power supply backup methods.

While the Bonitron Ride-Thru does not act as a back-up power supply in the case of a complete power interruption, it does provide excellent ride through capability for short duration (2 second) line voltage sags. These modules are much more cost effective than batteries, add-on capacitors, uninterruptible power supplies (UPS), or motor-generator sets. The great majority (~90%) of line voltage sags occurring in three-phase distribution systems have a magnitude (decrease from nominal) less than 50% and a duration under 0.5 seconds.

The modular design of the Bonitron M3460 Ride-Thru makes retrofit to an existing ASD simple. Only six electrical connections (three-phase AC, ±DC bus, and ground) are required for operation. Status outputs are available for PLC control and monitoring. The absence of batteries or capacitors in the Bonitron M3460 Ride-Thru results in low maintenance and long life expectancy. The capability to fully load test the modules and drives under normal line conditions without switches also increases system reliability.

Web Site: **www.bonitron.com**

Device Specifications Sizing and Costs

All costs shown in this section are in U.S. Dollars.

Constant Voltage Transformer (CVT)
(Sola/Hevi-Duty. Ph: 1-800-377-4384, www.sola-hevi-duty.com)
120 VA Catalog No: 63-23-112-4, Cost $245, (8.62" X 3.31 " X 5.18 ", 15 lbs)
250 VA Catalog No: 63-23-125-4, Cost $400, (9.88" X 4.50" X 7.44", 27 lbs)
500 VA Catalog No: 63-23-150-8, Cost $650, (12.69" X7.78" X 6.44", 37 lbs)
750 VA Catalog No: 63-23-175-8. Cost $700, (13.69" X 7.78" X 6.44", 52 lbs)
1000 VA Catalog No: 63-23-210-8, Cost $850, (16.75" X 7.78" X 6.44", 62 lbs)
1500 VA Catalog No: 63-23-215-8, Cost $1100 (16.44" X 10.56" X 9.03", 95 lbs)
2000 VA Catalog No: 63-23-220-8, Cost $1200 (17" X 11" X 9", 109 lbs)
5000 VA Catalog No: 63-23-250-8, Cost $2907 (28" X 11" X 9", 222 lbs)
7500 VA Catalog No: 63-28-275-8, Cost $3829 (28" X 24" X 9", 362 lbs)
15,000 VA Catalog No: 63-28-315-8, Cost $6700 (28" X 36" X 9", 710 lbs)

Sizing Guidelines for Constant Voltage Transformers: CVTs are primarily sized based on how much voltage sag protection is required and its ability to handle inrush current of the load. Typically CVTs are sized at least 2.5 times the VA rating of the load for voltage sag protection up to 55-60% of nominal. For inrush sizing, the maximum inrush current of the load should be less than 5 times the steady state current rating of the CVT.

Dip Proofing Inverters (DPI)

Contact: Ph: (303)364-4368 , www.dipproof.com, www.measurelogic.com)

Price List
Voltage Dip-Proofing Inverters and Accessories

Stock #	Model	VA*	Voltage	Dimensions in (H x W x D)	Price ($)
257	DPI52S10-12	100	120	9.30 x 5.90 x 4.33	550.00
258	DPI52S25-12	250	120	9.30 x 5.90 x 4.33	790.00
259	DPI52S50-12	500	120	11.26 x 5.90 x 4.33	1 280.00
256	DPI52L1K12	1000	120	12.28 x 12.24 x 6.38	1 680.00
255	DPI52L2K12	2000	120	16.22 x 12.24 x 6.38	2 220.00
254	DPI52L3K12	3000	120	20.16 x 12.24 x 6.38	2 680.00
262	DPI52S10-23	100	230	9.30 x 5.90 x 4.33	550.00
260	DPI52S25-23	250	230	9.30 x 5.90 x 4.33	790.00
261	DPI52S50-23	500	230	11.26 x 5.90 x 4.33	1 280.00
252	DPI52L1K5-23	1500	230	12.28 x 12.24 x 6.38	1 890.00
251	DPI52L3K23	3000	230	16.22 x 12.24 x 6.38	2 680.00
250	DPI52L4K5-23	4500	230	20.16 x 12.24 x 6.38	3 040.00

163	DPI BPSW-40	40 amp Bypass switch - housed	250.00
187	DPI BPSW-10	10 amp Bypass switch - housed	195.00
180	DPI 3000DE	2.5 amp 120V Tester/Demonstrator	1800.00

* Note VA power rating is for an *inductive* load; for example contactor coils.

Prices: Exclude shipping and where applicable sales tax.
Delivery: From stock to 4 weeks ARO.
Shipping: Via Airborn Express 2nd day service unless specified otherwise.
Terms: Net 30 days upon approved credit, otherwise COD.
Currency: US Dollars.

Sizing Guidelines for Dip Proofing: The dip proofing units are primarily sized based on the amount of usable energy that is stored in the capacitor. For example, the 500 VA unit has 95 Watt-Second of usable energy and can support a 95-Watt load for 1 second. A 190Watt load can be held for ½ second by the same unit.

Uninterruptible Power Supplies (UPS)

(Best Power Phone: 608-565-7200, www.bestpower.com)

Model FE500 (500VA/350W) Catalog No FE500DDAABBA Price $949

Model FE700 (700VA/500W) Catalog No FE700DDAABBA Price $1,049

Model FE850 (850VA/600W) Catalog No FE850DDAABBA Price $1,229

Model FE1.4 (1.4 kVA/1kW) Catalog No FE1.4KDDAABCA Price $ 1,999

Model FE10 (10kVA/7.5kW) Catalog No FE10KFKERAAB Price $ 9,995

Dynamic Sag Corrector (DySC)

(Phone 1-800-226-5028, www.softswitch.com)

MINIDySC - Single-Phase, 120 Volts, 2 Wire

MODEL NO.	DESCRIPTION	kVA	WEIGHT	DIMENSIONS	LIST PRICE
DySC 2A-120V-1P-2W-SO	Standard Outage	0.25	*	*	*
DySC 6.25A-120V-1P-2W-SO	Standard Outage	0.75	13.5	18.125x8.5x3.75	$727
DySC 12.5A-120V-1P-2W-EO	Ext. Outage / Line Cord	1.5	16 lbs	4"x9.5"x16.5"	$1,090
DySC 12.5A-120V-1P-2W-WM	Ext. Outage / Wall Mount	1.5	16 lbs	20"x12"x3.5"	$1,090
DySC 25A-120V-1P-2W-SO	Standard Outage	3	20 lbs	20"x12"x3.5"	$1,690
DySC 25A-120V-1P-2W-EO	Extended Outage	3	33 lbs	20"x19"x3.5"	$2,450
MB 35A-120V-1P-2W-10K	Manual Bypass	3		26"x20"x6"	$525
DySC 50A-120V-1P-2W-SO	Standard Outage	6	31 lbs	20"x19"x3.5"	$3,050
DySC 50A-120V-1P-2W-EO	Extended Outage	6	50 lbs	20"x23"x7"	$4,270
MB 70-120V-1P-2W-10K	Manual Bypass	6		26"x20"x6"	$605
DySC 100A-120V-1P-2W-SO	Standard Outage	12		20"x24"x12"	$4,210
DySC 100A-120V-1P-2W-EO	Extended Outage	12		36"x24"x12"	$5,890

PRODySC - Three-Phase, 480 Volts, 3 Wire

MODEL NO.	DESCRIPTION	kVA	WEIGHT	DIMENSIONS	LIST PRICE
DySC 12.5A-480V-3P-3W-EO	Ext. Outage / Wall Mount	10	160 lbs	32"x24"x13"	$9,770
MB 35A-480V-3P-3W-18K	Manual Bypass	10		65"x27"x15"	$1,940
AB 35A-480V-3P-3W-18K	Auto Bypass	10		65"x27"x15"	$5,480
DySC 25A-480V-3P-3W-SO	Standard Outage	21	160 lbs	32"x24"x13"	$11,000
DySC 25A-480V-3P-3W-EO	Extended Outage	21	199 lbs	32"x24"x13"	$15,400
MB 35A-480V-3P-3W-18K	Manual Bypass	21		65"x27"x15"	$1,940
AB 35A-480V-3P-3W-18K	Auto Bypass	21		65"x27"x15"	$5,480
DySC 50A-480V-3P-3W-SO	Standard Outage	42	266 lbs	36"x36"x13"	$14,510
DySC 50A-480V-3P-3W-EO	Extended Outage	42	326 lbs	36"x36"x13"	$20,310
MB 70A-480V-3P-3W-18K	Manual Bypass	42		65"x27"x15"	$2,050
AB 70A-480V-3P-3W-18K	Auto Bypass	42		65"x27"x15"	$5,600
DySC 100A-480V-3P-3W-SO	Standard Outage	83		55"x29"x24"	$26,090
DySC 100A-480V-3P-3W-EO	Extended Outage	83	750 lbs	65"x29"x24"	$36,530
MB 125A-480V-3P-3W-18K	Manual Bypass	83		65"x27"x15"	$3,125
AB 125A-480V-3P-3W-18K	Auto Bypass	83		65"x27"x15"	$6,655

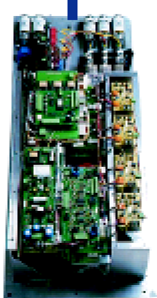
Coil Hold-In Devices

Contact for latest pricing: www.scrcontrols.com or www.pqsi.com
($80 Typical)

Bonitron

M3460R Open Chassis Power Dip Ride-Thru Modules

Bonitron's Ride-Thru Modules are used with Adjustable Speed Drives to provide protection from AC line voltage fluctuations. These modules provide protection from a voltage sag, a few cycle dip from a transient, or the total loss of one phase. This provides the security of "riding through" these events **up to 2 seconds without loss of control of motor speed!** They also protect against total motor drive shutdown and eliminate concerns associated with the various other methods of power supply backup. Available from 6 kW up to 200 kW, these can be outfitted for a single drive or an entire process line. The models listed below are rated for 50% dip, 2 second duration.



Model Number and Pricing

System Input Voltage VAC	System Power kW	DC Bus Amps	Minimum Output Voltage VDC	Fusing Provided		Model Number	List Price
				AC	DC		
M3460R Standard Open Chassis Ride-Thru							
460	6	9.5	590	Yes	Yes	3460R-4B1-006A	$ 2,373
460	12	19	590	Yes	Yes	3460R-4B1-012A	$ 3,651
460	24	38	590	Yes	Yes	3460R-4B1-024A	$ 4,425
460	50	80	590	Yes	Yes	3460R-4R3-050A	$ 9,657
460	75	120	590	Yes	Yes	3460R-4R3-075A	$ 13,546
460	100	160	590	Yes	Yes	3460R-4R1-100A	$ 14,594
460	150	240	590	Yes	Yes	3460R-4R1-150A	$ 18,223
460	200	320	590	Yes	Yes	3460R-4R2-200A	$ 21,866

www.bonitron.com